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FINAL REPORT

VOLUME I

DESIGN, FABRICATION AND ACCEPTANCE TESTING OF A ZERO GRAVITY WHOLE BODY SHOWER

Contract NAS1-11339

PREPARED FOR LYNDON B. JOHNSON SPACE CENTER
OF THE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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July, 1973

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FOREWORD

This final report was prepared by Martin Marietta under Contract No. NAS1-11339, "Design, Fabrication and Acceptance Testing of a Zero Gravity Whole Body Shower," for NASA-JSC. The final report is contained in two volumes. Volume I is a narrative of tasks performed during the contract. Volume II contains detailed design and test data.

TABLE OF CONTENTS

Figures

Figures | Page

Tables

Tables

DESIGN, FABRICATION AND ACCEPTANCE TESTING OF A ZERO GRAVITY WHOLE BODY SHOWER

SUMMARY

This report describes the three - task effort conducted for NASA-JSC under NASA Contract NAS1-11339 to design, fabricate and acceptance test a zero-gravity whole body shower for the Space Station Prototype. The technology base for the system design was that established under previous development contracts (NAS1-9819, NAS1-9819 Mod I) performed by Martin Marietta.

During Task 1 of the contract reported herein, clothes and dish washer/dryer concepts were formulated with consideration given to integrating such a system with the overall shower design. Water recycling methods to effect vehicle weight savings were investigated and it was concluded that reusing wash and/or rinse water resulted in weight savings which were not sufficient to outweigh the added degree of hardware complexity. Separate units or combinations thereof to wash and dry clothing and dishes were analyzed on the basis of total vehicle equivalent weight, power and volume. It was also concluded that whatever clothes/dish washer configuration is chosen, essentially the same sterilization procedures and cleansing agents would be utilized, and a weight penalty, depending on the concept chosen, of approximately 2.5 lb/day (1.14 kg/day) is necessary.

Conceptual designs for various subsystems of the shower were also formulated as part of Task 1. Preliminary tests and calculations were performed on the evaporative drying (air drag) versus the towel drying (vacuum pickup) concepts of showering, and on other related areas such as temperature and humidity ranges.

Task 2 involved the formulation of preliminary and final designs for the shower. A detailed comparison of the air drag vs. vacuum pick-up method was prepared that indicated the air drag concept results in more severe Space Station weight penalties; therefore, the preliminary system design was based on utilizing the vacuum pickup method. Tests were performed to determine the optimum methods of storing, heating and sterilizing the cleansing agent utilized in the shower; it was concluded that individual packages of pre-sterilized cleansing agent should be used. Integration features with the Space Station Prototype (SSP) system were defined and incorporated into the shower design as necessary.

Based on preliminary and critical design reviews the final system design was prepared and presented in detail. The design has separate modules for the showering area, electrical and mechanical components and has special features to permit easy component access for in-flight maintanence by component replacement. (Figures 1-18, referred to in the following text, show in detail the final shower configuration.) Shower faults and failures are automatically detected from an instrumentation subsystem which interfaces with a computer oriented space station fault detection and isolation analysis system. Also in Task 2 interfaces with the SSP were further refined, maintenance procedures were formulated, and materials definition was completed.

For Task 3, the shower assembly was fabricated and tested. An alternate air blower configuration was prepared in order to reduce overall system noise from the high levels (95db at 2000 hertz) caused by the SSP common 400 hertz blower. In addition, a revised liquid level sensing system was incorporated into the liquid/gas separator sump to eliminate problems caused by cleansing agent (soap) sudsing. The shower assembly successfully completed the functional, performance and demonstration tests as required. Six showers per day were taken as part of the test program. An average of .66 gal water per shower, which required approximately 9.7 min., was used at an average 59.7 watts power consumption.

1.0 INTRODUCTION

With the advent of more sophisticated manned space missions including increased crew size, mission duration and vehicle volume, more emphasis is being placed on overall crew comfort. One of the habitability features which can significantly enhance crew comfort and motivation is the ability to cleanse the entire body in a zero gravity environment.

Recent research and development programs have established the ability of the zero gravity whole body shower (ZGWBS) to maintain a comfortable environment in which the crewman can safely cleanse and dry the body. The purpose of this program was to further advance the technology of whole body bathing and to demonstrate technological readiness including in-flight maintainence by component replacement for flight applications. The shower assembly contains zero-gravity design features but is primarily designed for earth environment testing in conjunction with other SSP hardware.

The three-task effort included conceptual designs and system tradeoffs in Task 1, preliminary and final design in Task 2, and fabrication and testing in Task 3. Based on overall contract performance, the final design of the ZGWBS successfully demonstrated satisfactory compliance with all specified parameters.

1.1 Mission Model

The design of the shower assembly and the investigation of clothes and dish washer/dryer concepts are based on the following models:

Mission Model

Mission Duration	2 years
Resupply Capability	180 days
Gravity Mode	0 to 1 g
Mission Objective	Space station/space base

Vehicle Model

Compartment Size:		
Diameter (in.)		164
Height (in.)		82
Crew Model		
Number of crewman		6
Height of man (ft)		6
Weight of man (lb)		160-190
Metabolic Activity (zero g) Avg/24 hours		150% Basal Metabolism Rate
Atmosphere Model		
Cabin Total Pressure		10.0 to 14.7 psia
Gas Composition		3.5 psia Oxygen Diluent Nitrogen
Carbon Dioxide		0 to 3.0 mm Hg
Temperature (dry bulb)		65^{o} to $75^{o}F$ adjustable
Dew Point		46 to $57^{o}F$, for any dry bulb temp.
Water Use Model		
Shower	80 lb/man-day	48.0 lb/day (20.8 kg/day)
Clothes Washing		210 lb/day (95.5 kg/day)
Dish Washing		90 lb/day (41.0 kg/day)

1.2 Subsystem Design Requirements

1.2.1 General

The general design requirements of the ZGWBS include the following:

(a) Sufficient equipment to allow the crewman to bathe and dry the whole body, including the head, while in the shower.

(b) Provisions for the removal of body odors, perspiration, oils, hair and particulate matter from the shower subsystem.

(c) Provisions for controlling micro-organisms in the shower subsystem.

(d) Water collection features to retrieve the shower waste water.

(e) Controls and distribution features to regulate the shower input water.

(f) Adequate lighting, restraint devices, temperature, humidity, and contaminant control features to provide crew comfort and safety while in the shower.

(g) Cleaning agent storage and dispensing facilities.

1.2.2 Subsystem Requirements

Water Distribution and Controls - The ZGWBS includes a water distribution system (hose, valve and nozzle) which ensures proper cleaning with minimum water usage. Water that meets whole body bathing requirements is provided by the SSP water management subsystem. This water is delivered to the shower at a tank pressure of 28 psia. Provisions for heating the water to a comfortable temperature for bathing are included in the SSP water Management subsystem.

Cleansing Agent Storage and Dispensing - The ZGWBS utilizes a liquid cleansing agent contained in individual packages. Storage for the total supply of packages required (1080) is provided by the SSP system and the crewman obtains a package prior to each shower. The stall interior includes a package holder for use during showering.

Shower Stall Configuration - The shower stall (see Fig. 1) includes a transparent door and is sufficient in size to allow adequate movement of the crewman during showering and stall cleanup. Restraint devices are incorporated to facilitate bathing in zero and one gravity.

Water Collection - The water utilized for showering is retrieved by a vacuum pickup system and pumped to the SSP waste water management subsystem interface. The pickup system allows the crewman to collect water from free air and the stall walls and floor.

Maximum Shower Use - The maximum shower use is 6 showers in a 1.5 hour period with a 22.5 hour recovery time.

Design Loads - The shower system is designed to withstand a 10g loading in any direction, primarily for shipping reasons. A stress analysis has been performed to substantiate the configuration chosen. (See Appendix D)

Personal Comfort Provisions - The following parameters are maintained within the shower stall for the crewman's comfort and safety:

Air Temperature	75 to 110^{o}F (except if higher air heater temp. is chosen)
Humidity	55 to 80% (controlled by procedure)
Carbon Dioxide	0 to 3 mm Hg
Noise	NC-75 within stall NC-50 outside [89900000851--019 Assy Only]

Instrumentation and Controls - Operational status, subsystem performance, and fault detection and isolation are determined by the instrumentation and controls included in the ZGWBS system. The instrumentation provided is thoroughly compatible with the automatic checkout equipment (ACE) utilized in SSP procedures.

1.3 Reliability and Quality Assurance Requirements

The ZGWBS is designed to be inherently reliable at the subsystem level. Table 1 gives the reliability math model for the zero gravity shower. Reliability and quality assurance provisions on the program level are described in Drawing No. 89900000854, Final Reliability and Quality Program Plan, included in Volume II to this report.

TABLE 1 - SUBSYSTEM: ZERO GRAVITY SHOWER RELIABILITY MATH MODEL

ITEM	FAILURE MODE	QTY (N)	FAILURE RATE * x 10^{-6}	OPER. TIME (HRS)	N T	LAUNCH SPARES	RESULTING UNRELIABILITY
Water Valve & Nozzle	All Modes	1	1.0	270	0.000270	1 Spare	0.000001
Liquid/Gas Separator	1. External Leakage	1	.001	4320	0.000004	--	0.000004
	2. Clogging	1	1.0	270	0.000270	Assumes Ability to Clean	0.000001
	3. Liquid Level Switches	3	1.0	270	0.001620	Outlet Port 1 Spare	0.000001
Blower	1. Inoperative	1	10.89	270	0.003210	1 Spare	0.000006
	2. Speed Sensor	1	1.0	270		1 Spare	
Orifice	Clogging	1	Neg.	--	--	--	--
Flowmeter	1. Temp. Probe Assy	1	2.0	270	0.001215	1 Spare	0.000001
	2. Electronics	1	2.6	270			
Orifice	Clogging (Inlet Port)	1	1.0	270	0.000270	Assumes Ability to Clean Inlet Port	0.000001
Orifice	Clogging	1	Neg.	--	--	--	--
Heater	Fails Open	1	1.1	270	0.000297	1 Spare	0.000001
Temperature Sensor	Drift	3	1.0	270	0.000810	1 Spare	0.000001
Pump	1. Pump Inoperative	1	8.4	270			
	2. Relief Valve (Fail Open)	1	0.3	270	0.003774	1 Spare	0.000007
	3. External Leak (6-Seals)	1	0.33	4320			
Flowmeter	See Item FM3	1	4.5	270	0.001215	1 Spare	0.000001
Vacuum Pickup	Clogging	1	1.0	270	0.000270	Assumes Ability to Clean Inlet Screen	0.000001
Air Temp. Control Unit	Drift	1	2.5	270	0.000676	1 Spare	0.000001
Relays R2 Thru R10	All Modes	9	1.0	270	0.002430	1 Spare	0.000003
Switches S1	" "	1	0.14**	4320	0.000005	1 Spare	0.000001
S2	" "	1	0.14**	4320	0.000605	1 Spare	0.000001
S3	" "	1	0.02	4320	0.000086	Only Req. for Maint.	0.000086
S4	" "	1	0.14**	4320	0.000605	1 Spare	0.000001
Light Bulb	" "	4	1.0	270	0.000270	1 Spare	0.000001
Circuit Breaker CB1-5	" "	5	0.05	4320	0.001080	--	0.001080
	Total Expected Failures				0.019581		
	Reliability						.9988

* Failure Rates Selected From SSP Document A22 (System Reliability Report) ** Cyclic Failure Rate Converted to Hourly Assuming 6 Operations Per Day

FINAL SHOWER CONFIGURATION

FIGURES 1-18

(See Paragraph 4.0)

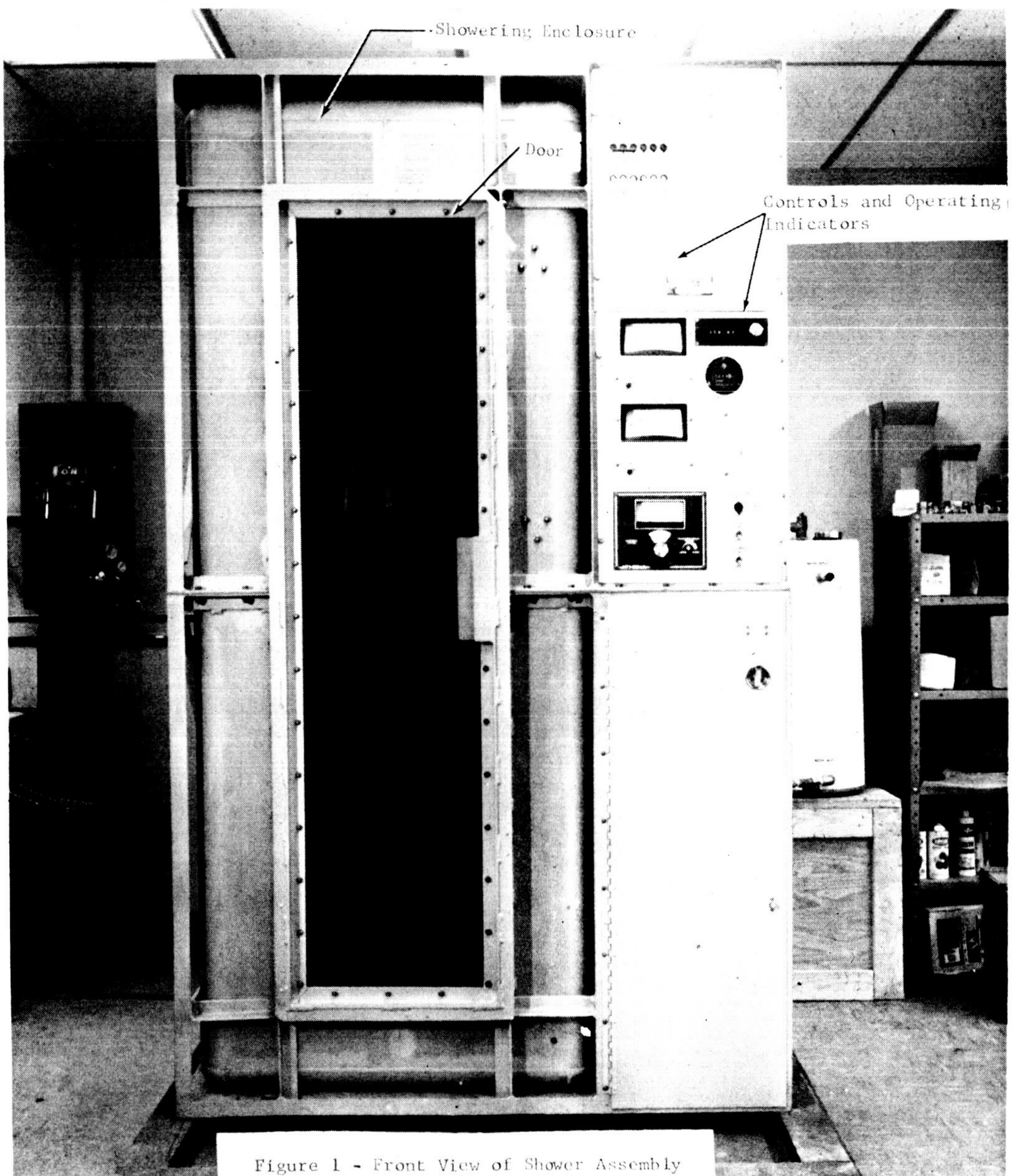


Figure 1 - Front View of Shower Assembly

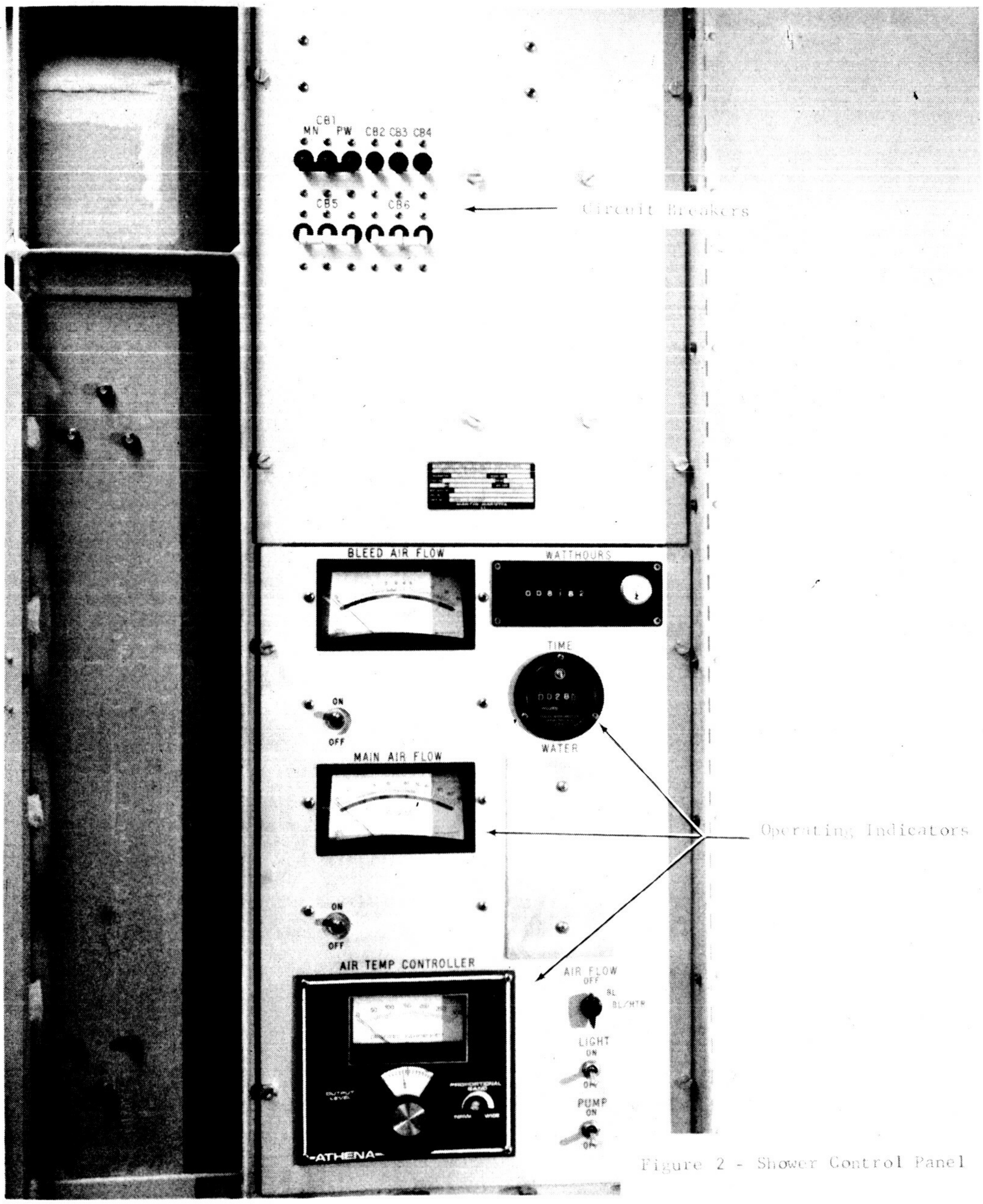


Figure 2 - Shower Control Panel

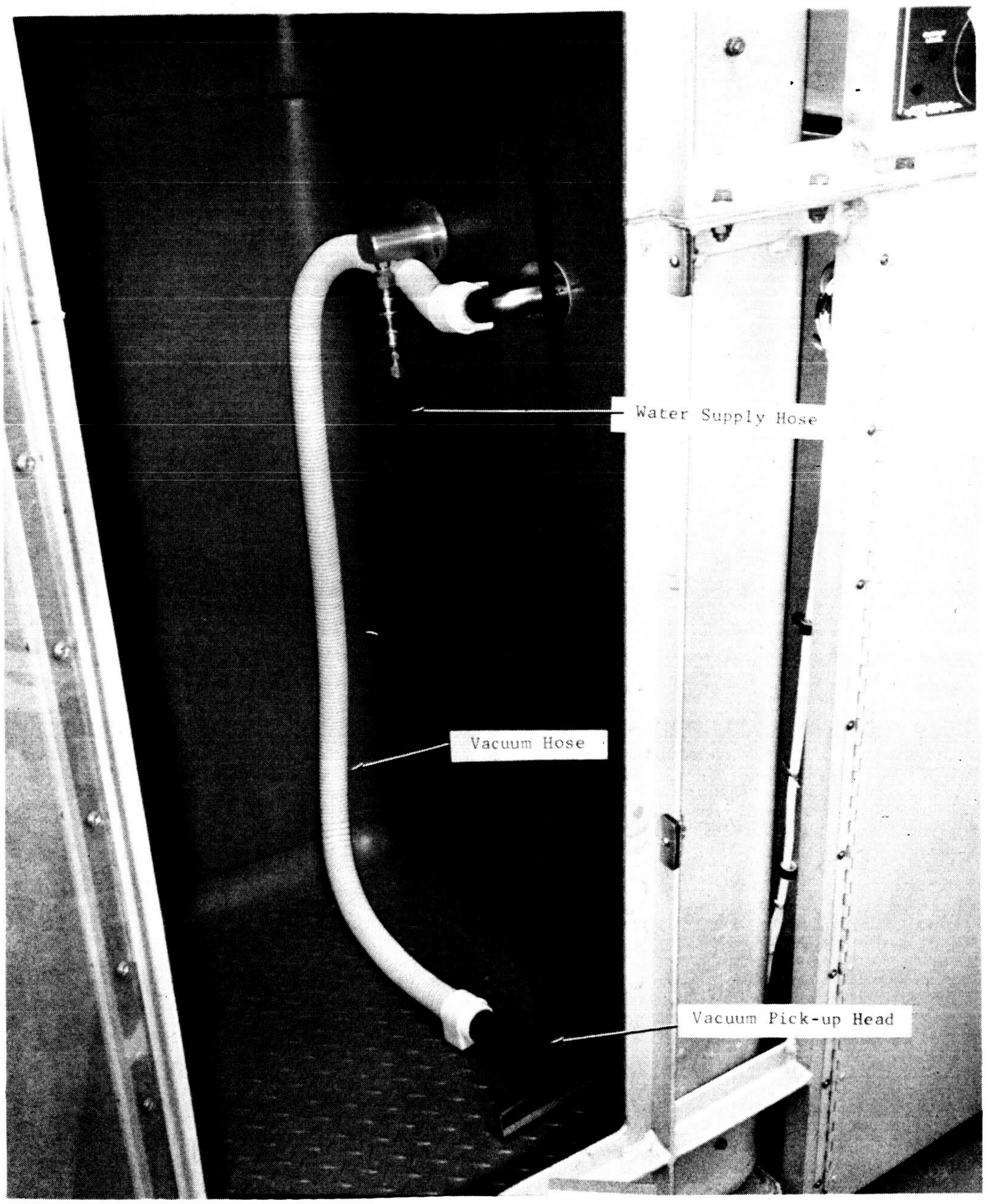


Figure 3 - Shower Stall, Bottom Half

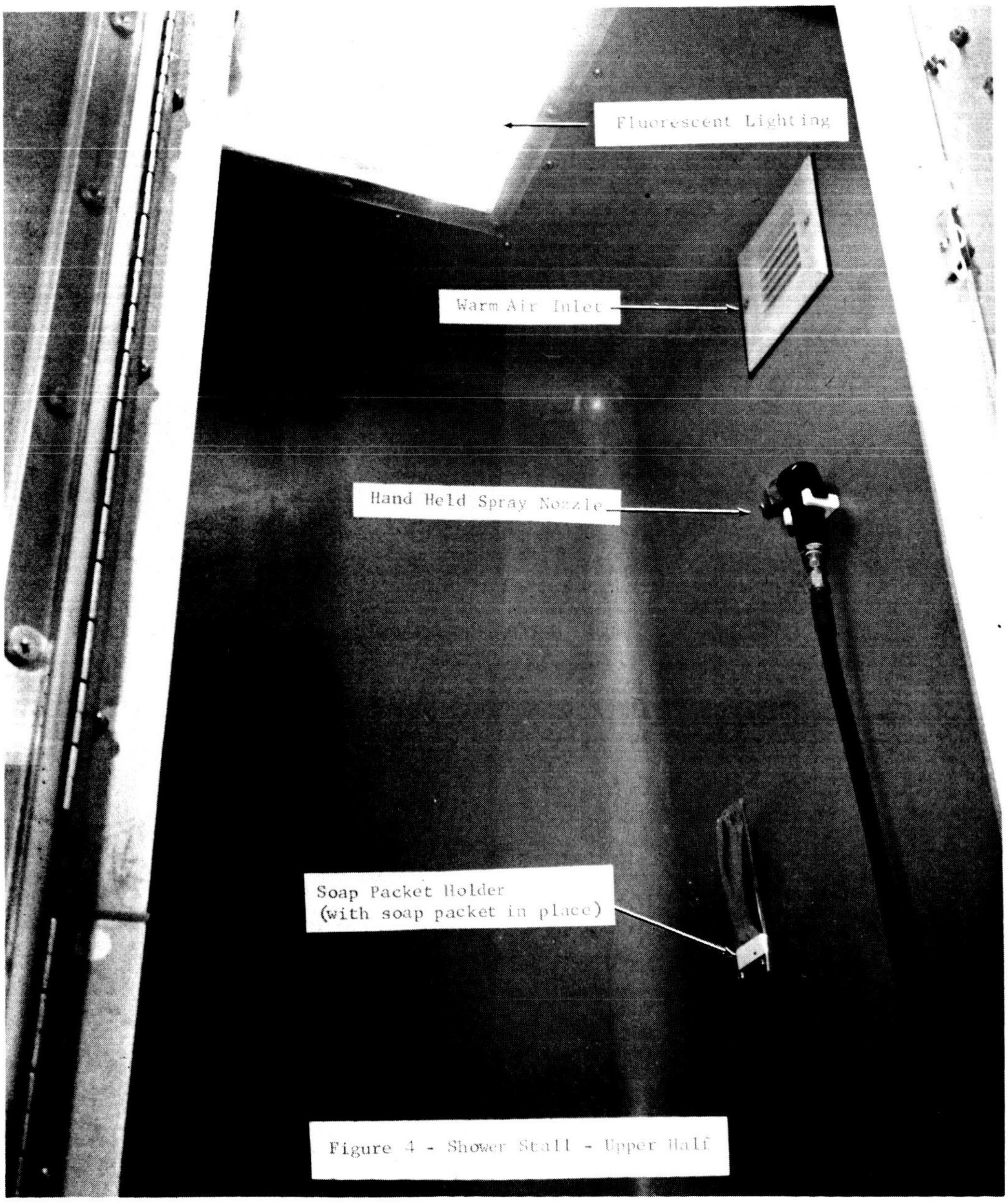


Figure 4 - Shower Stall - Upper Half

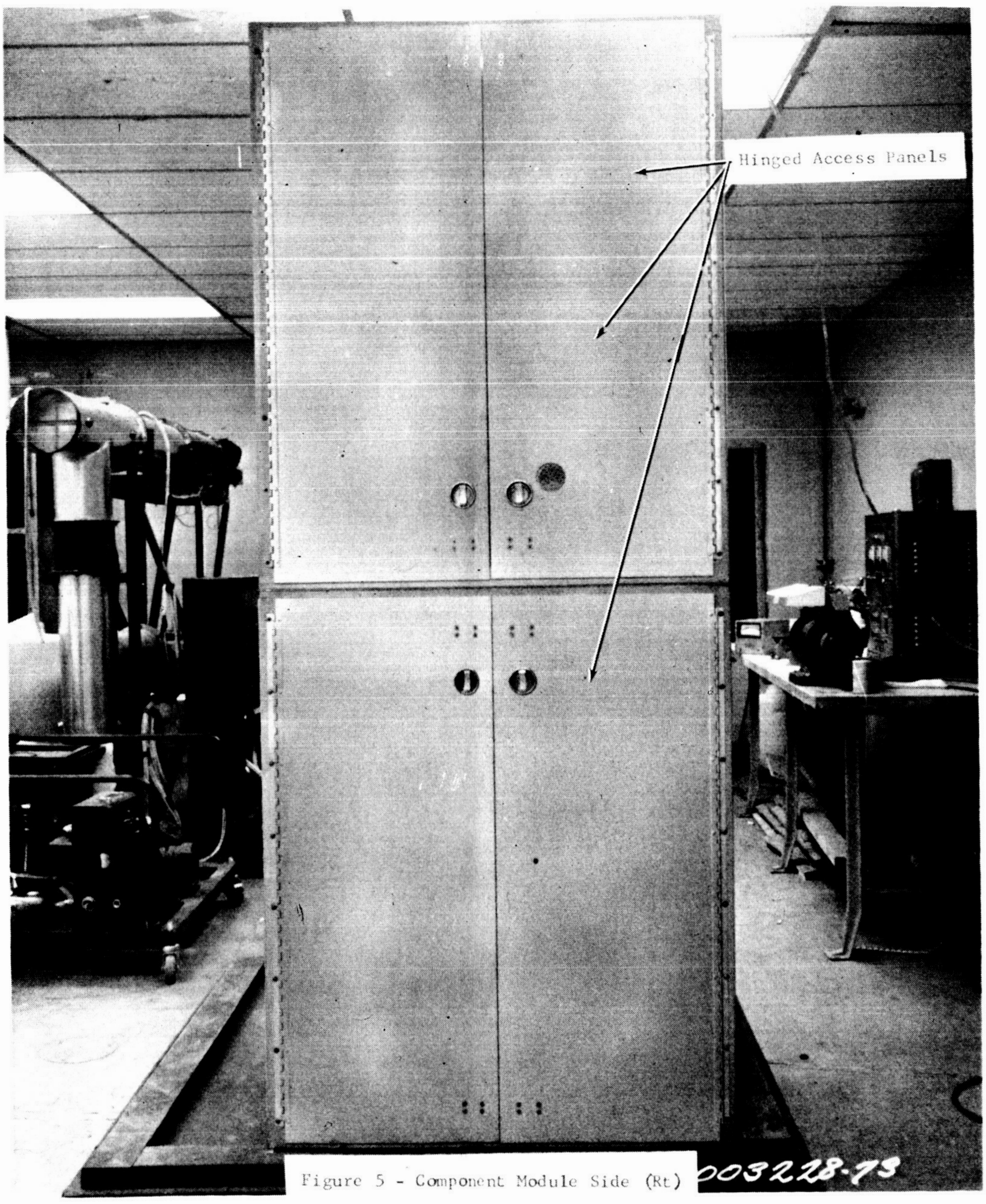


Figure 5 - Component Module Side (Rt)

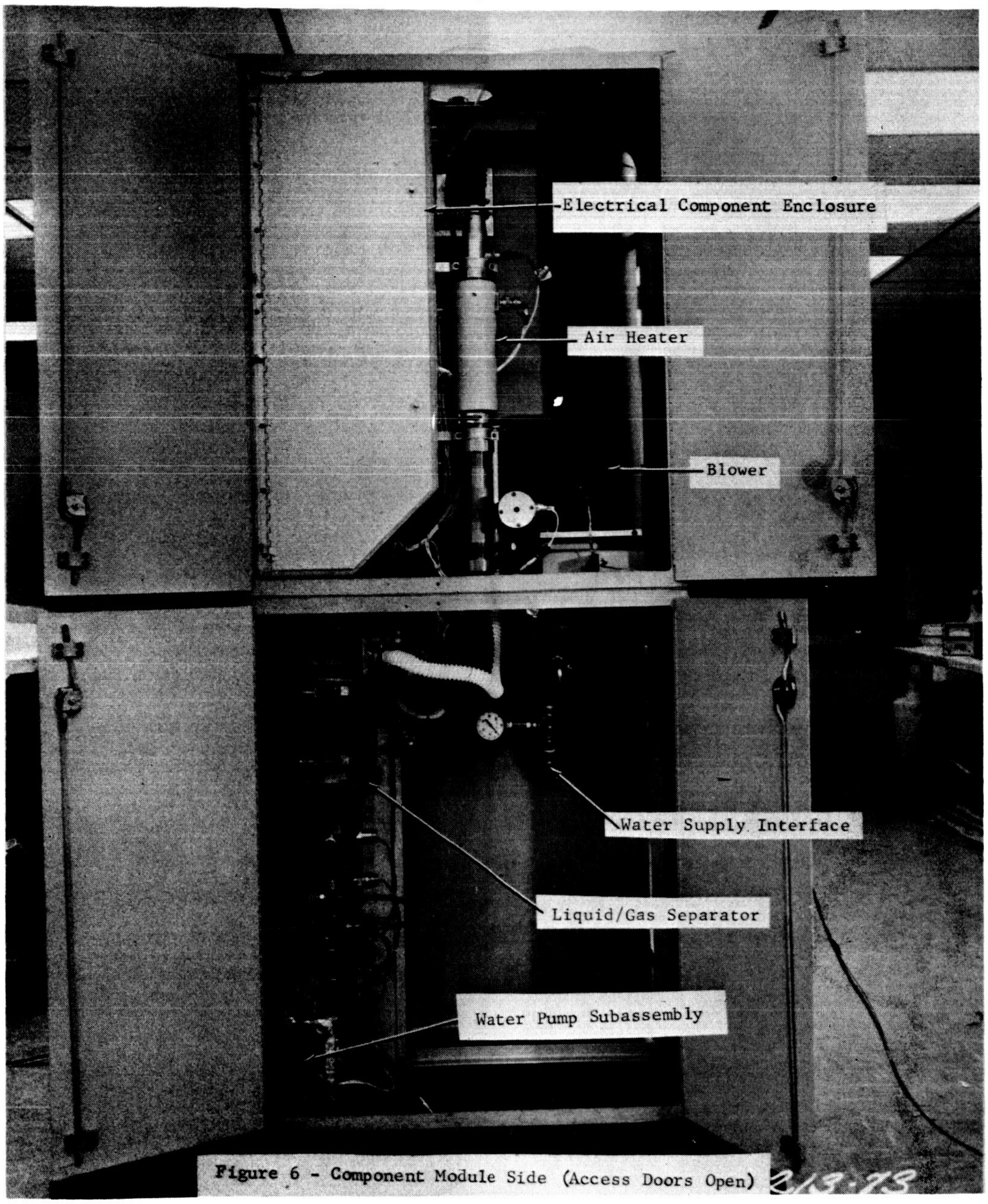


Figure 6 - Component Module Side (Access Doors Open)

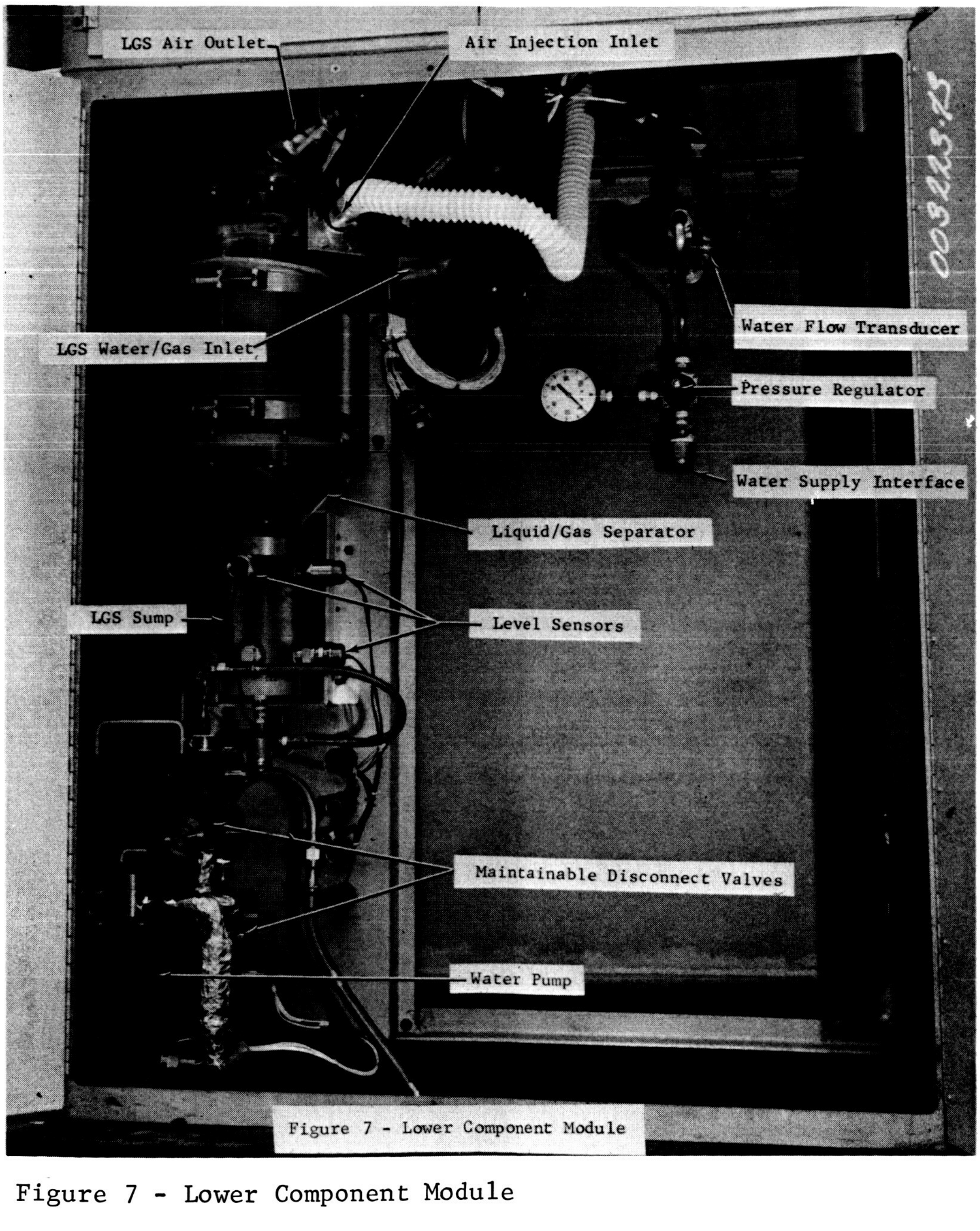


Figure 7 - Lower Component Module

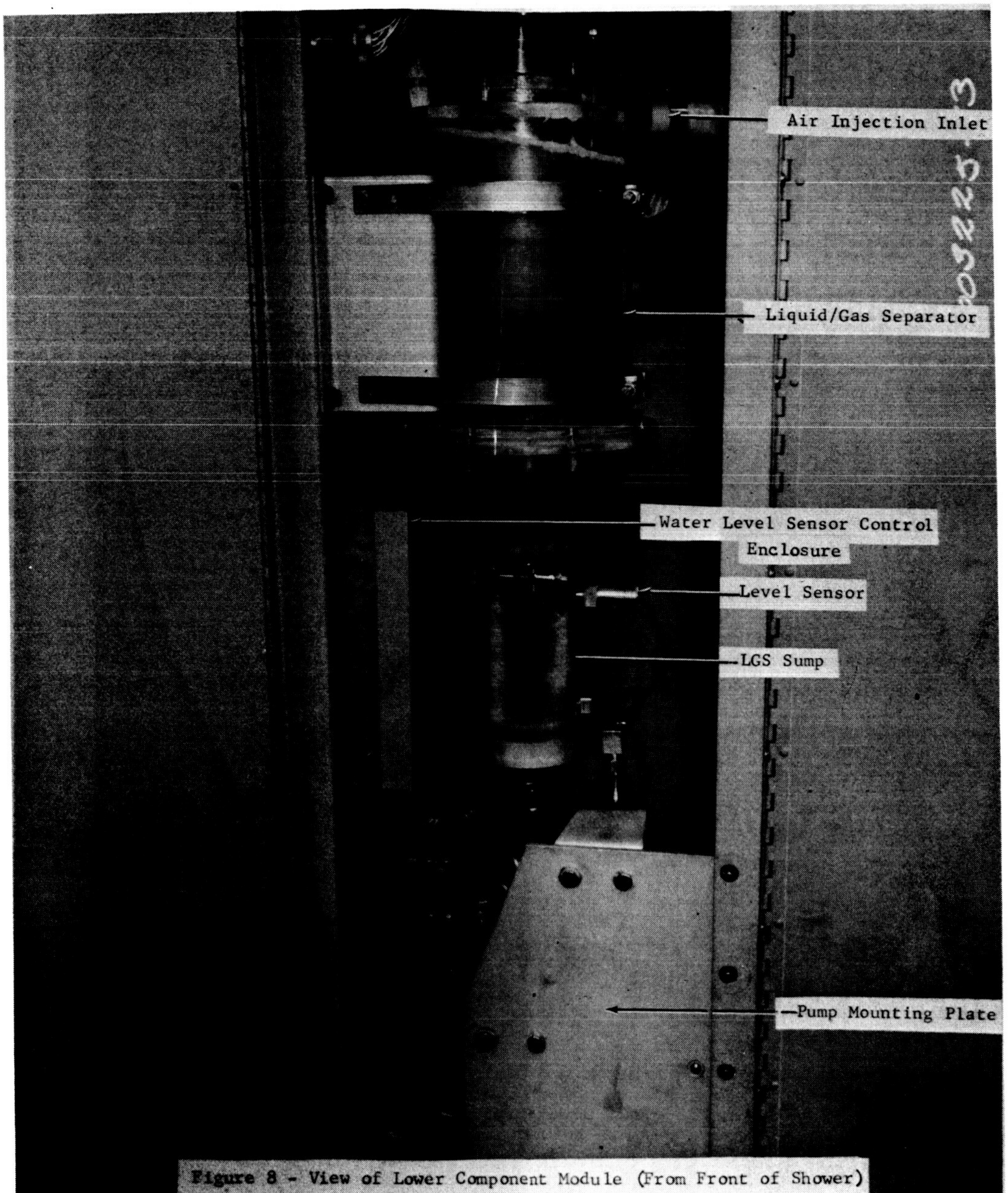


Figure 8 - View of Lower Component Module (From Front of Shower)

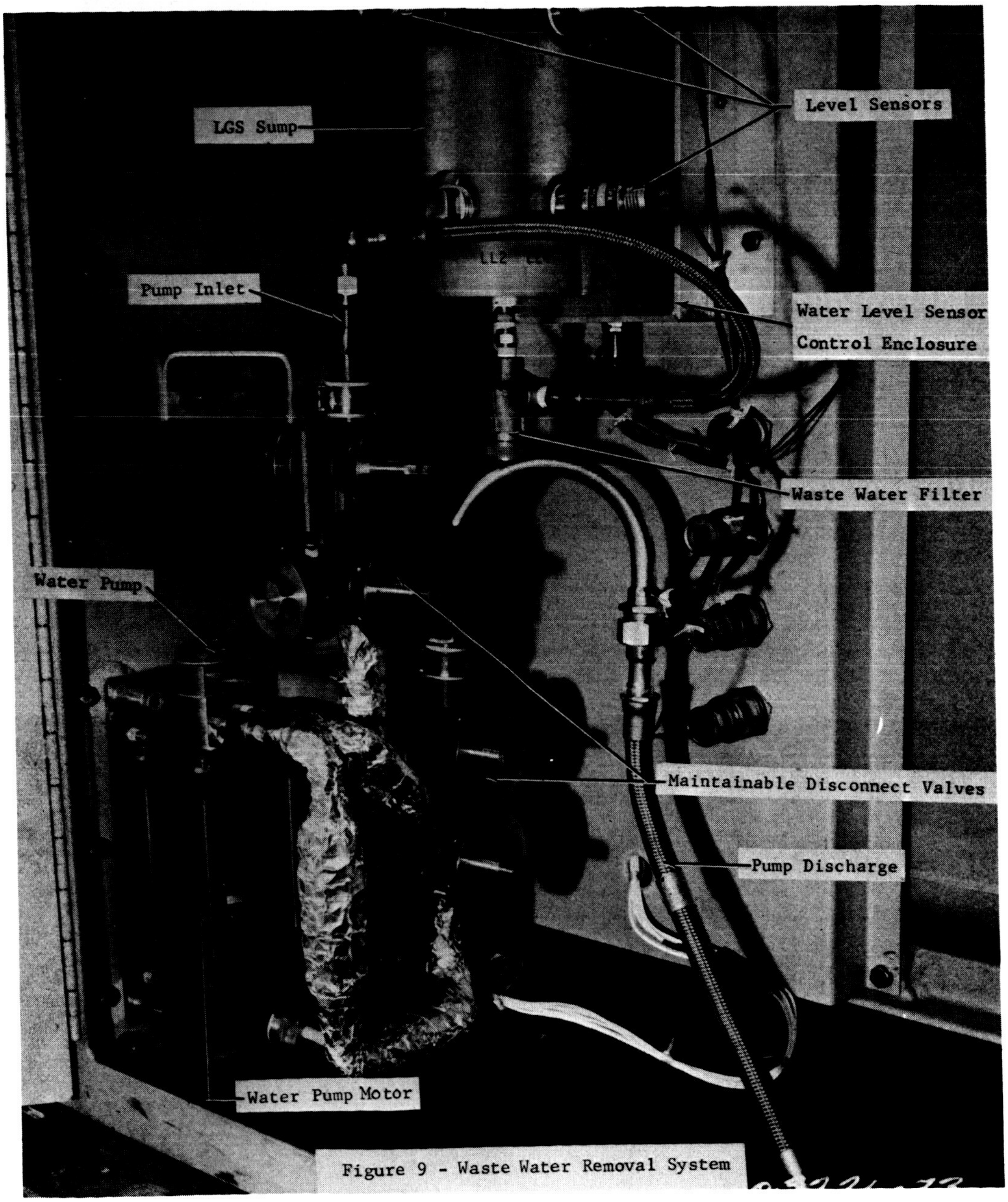


Figure 9 - Waste Water Removal System

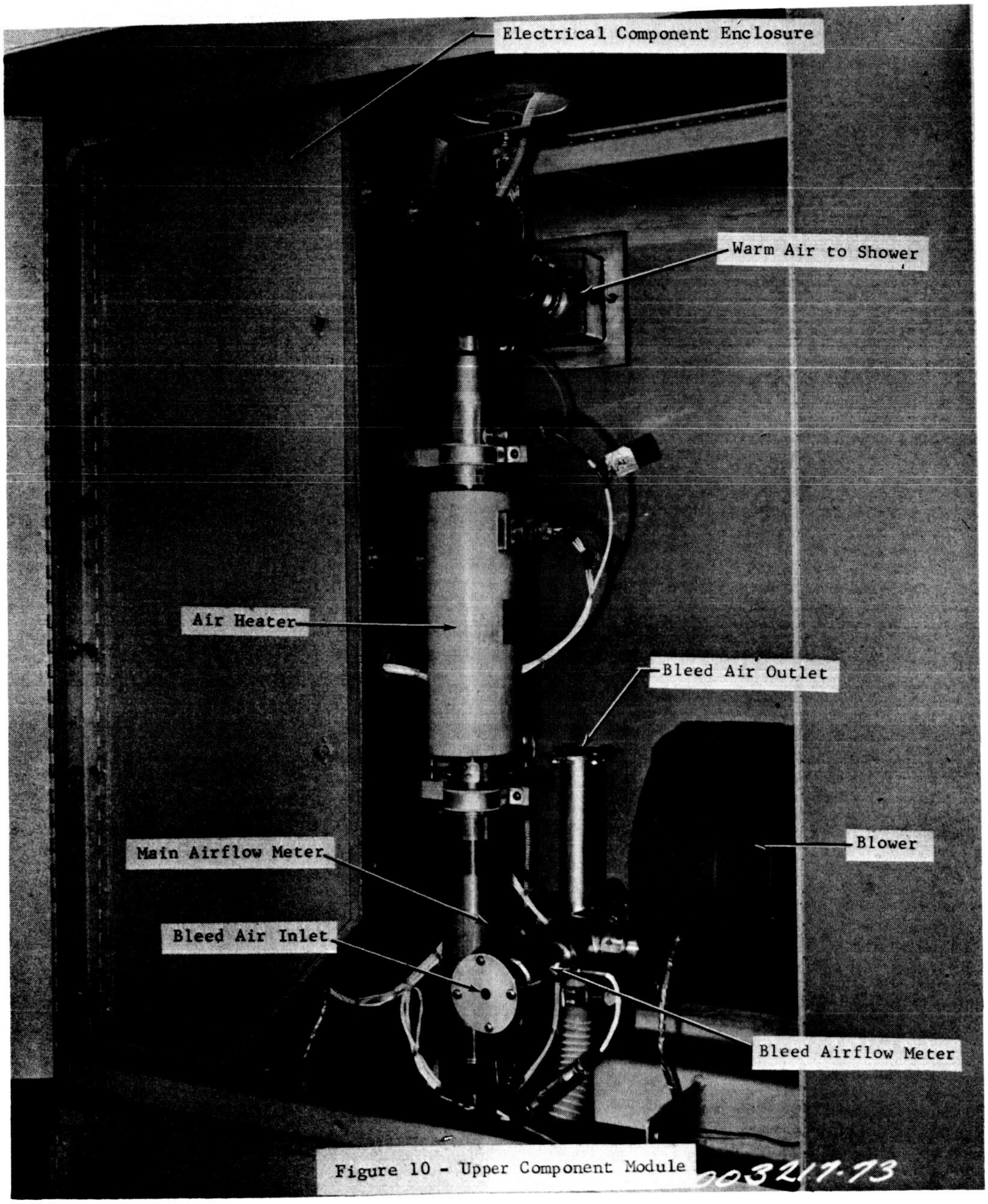


Figure 10 - Upper Component Module

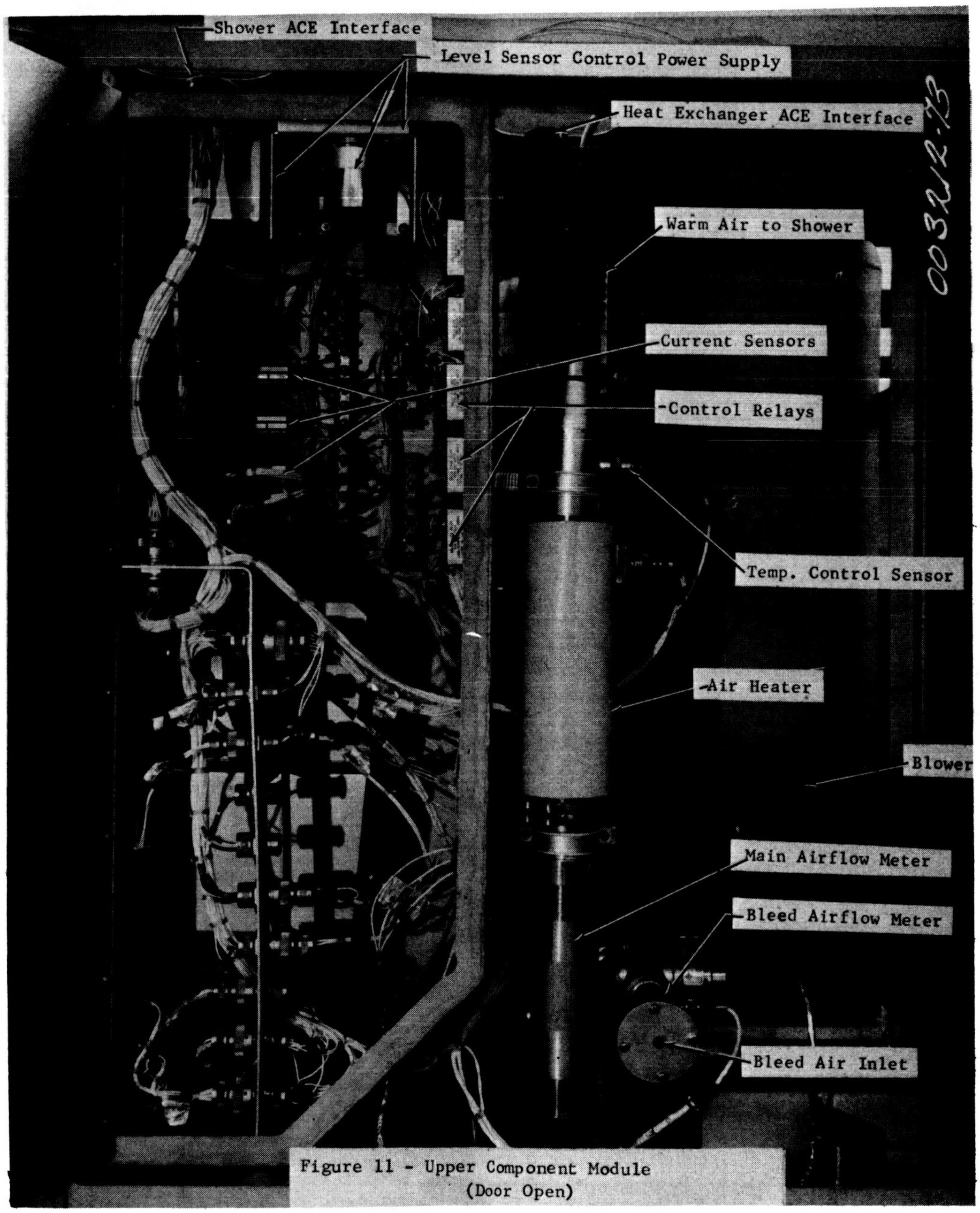


Figure 11 - Upper Component Module (Door Open)

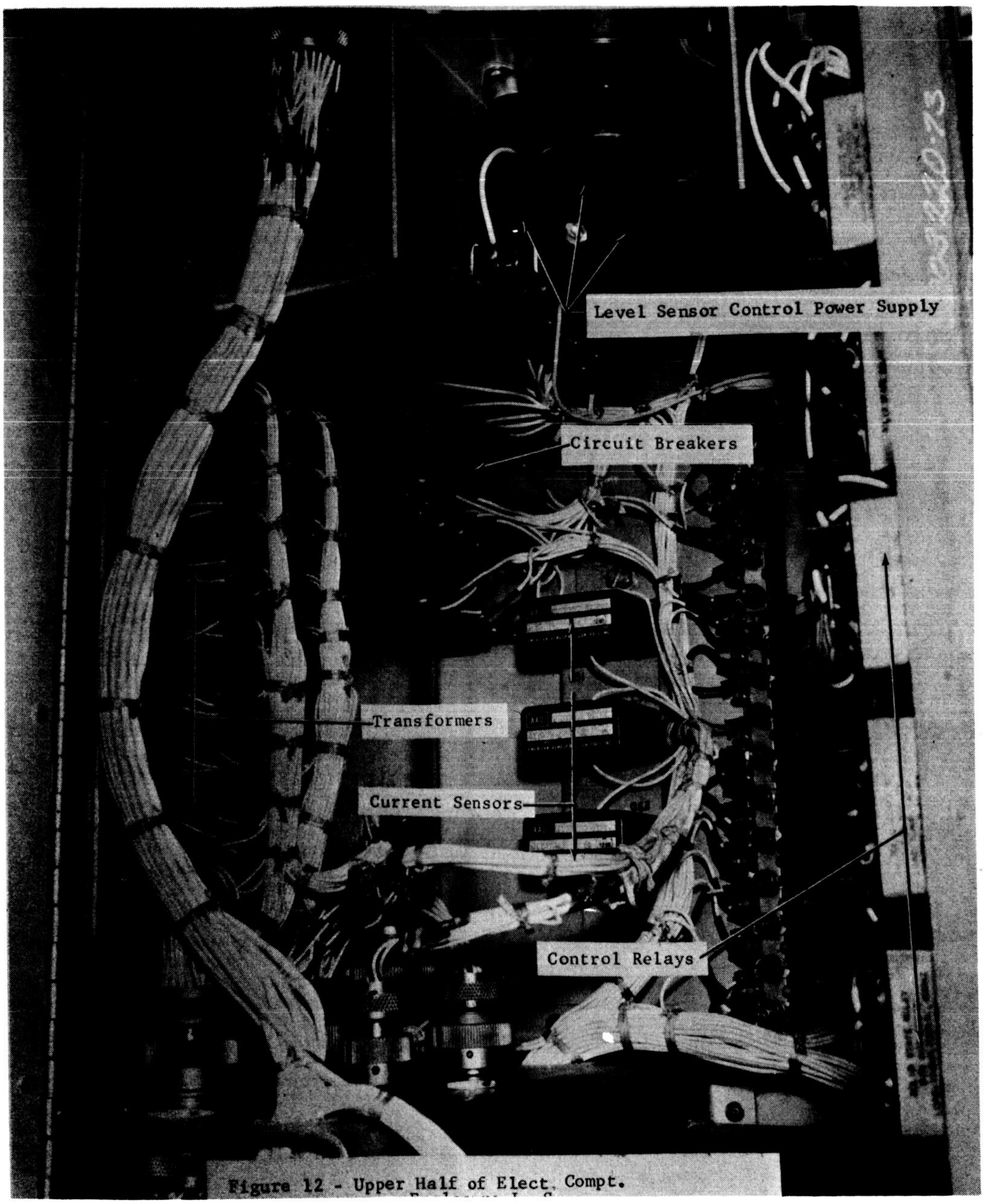


Figure 12 - Upper Half of Elect. Compt.
Enclosure L. S.

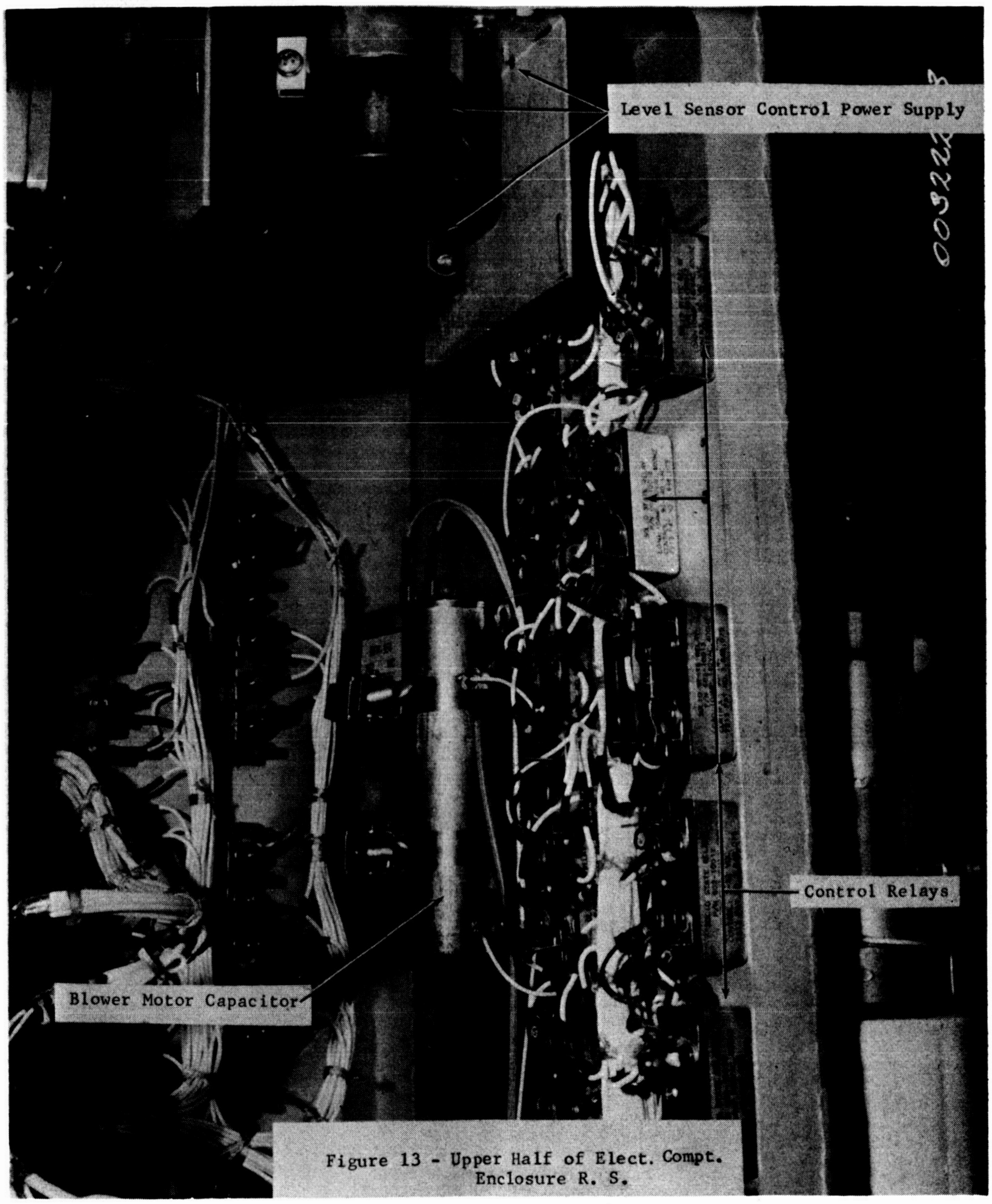


Figure 13 - Upper Half of Elect. Compt.
Enclosure R. S.

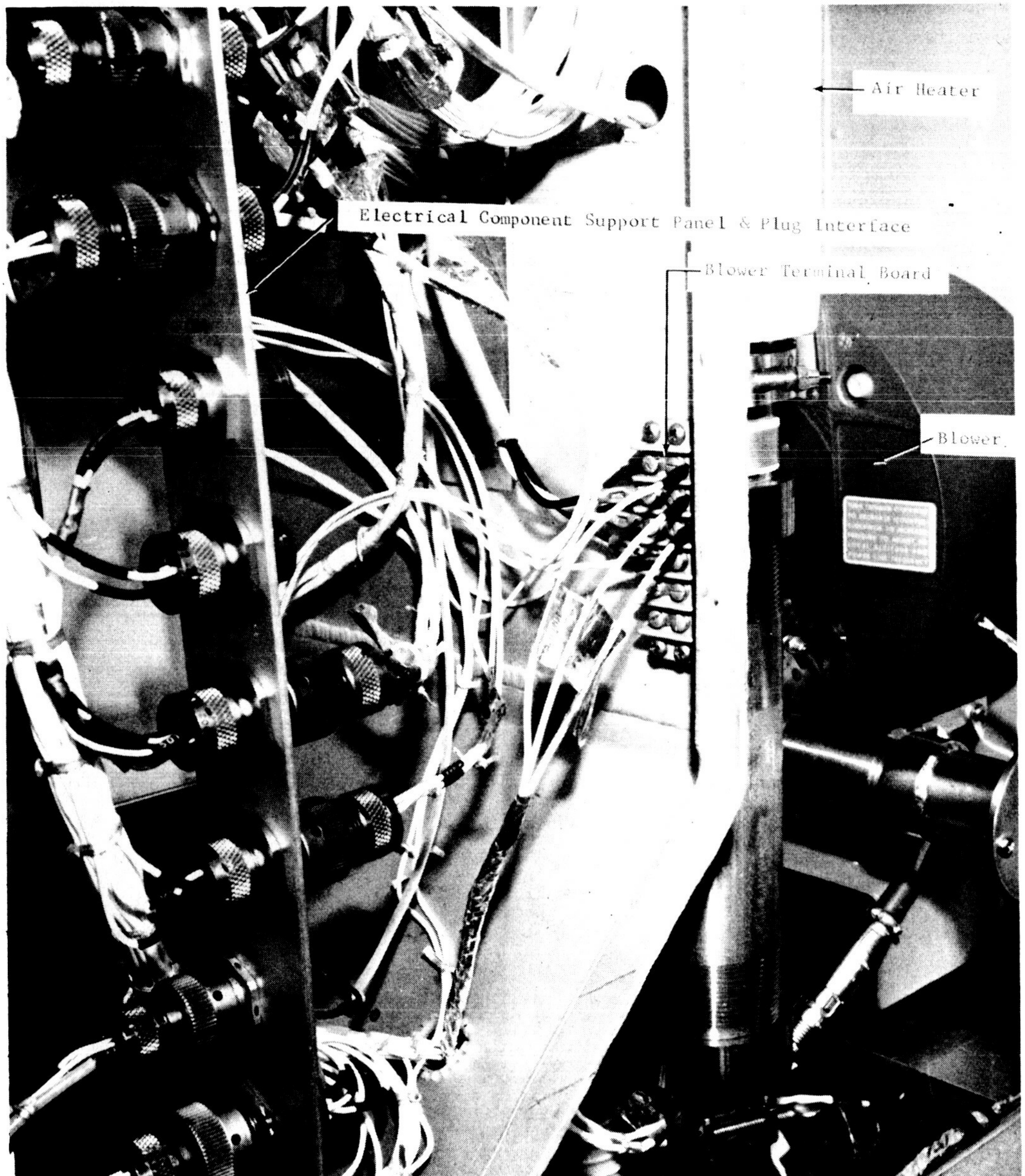


Figure 14 - Lower Half of Elect. Compt.
Enclosure R. S.

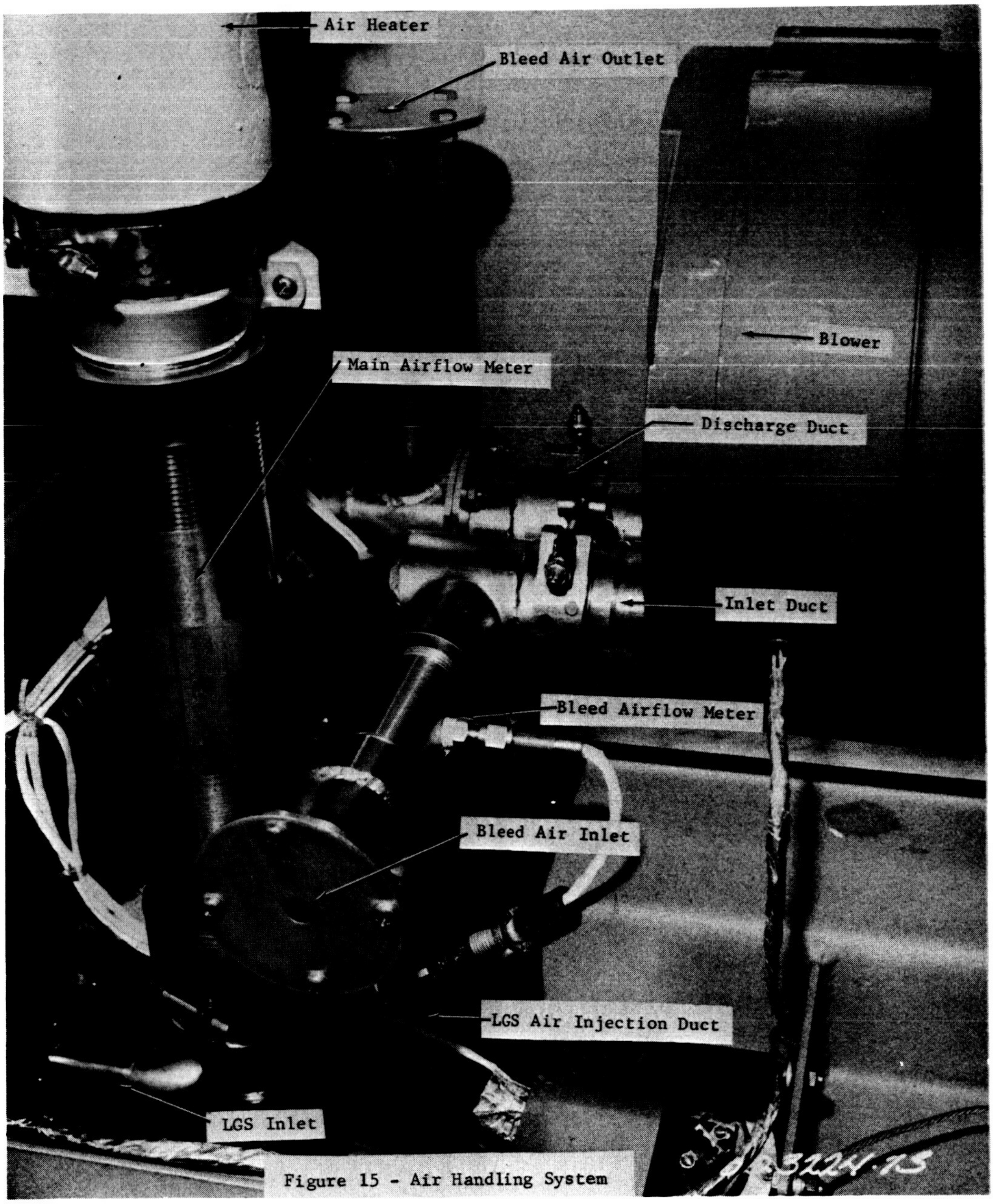


Figure 15 - Air Handling System

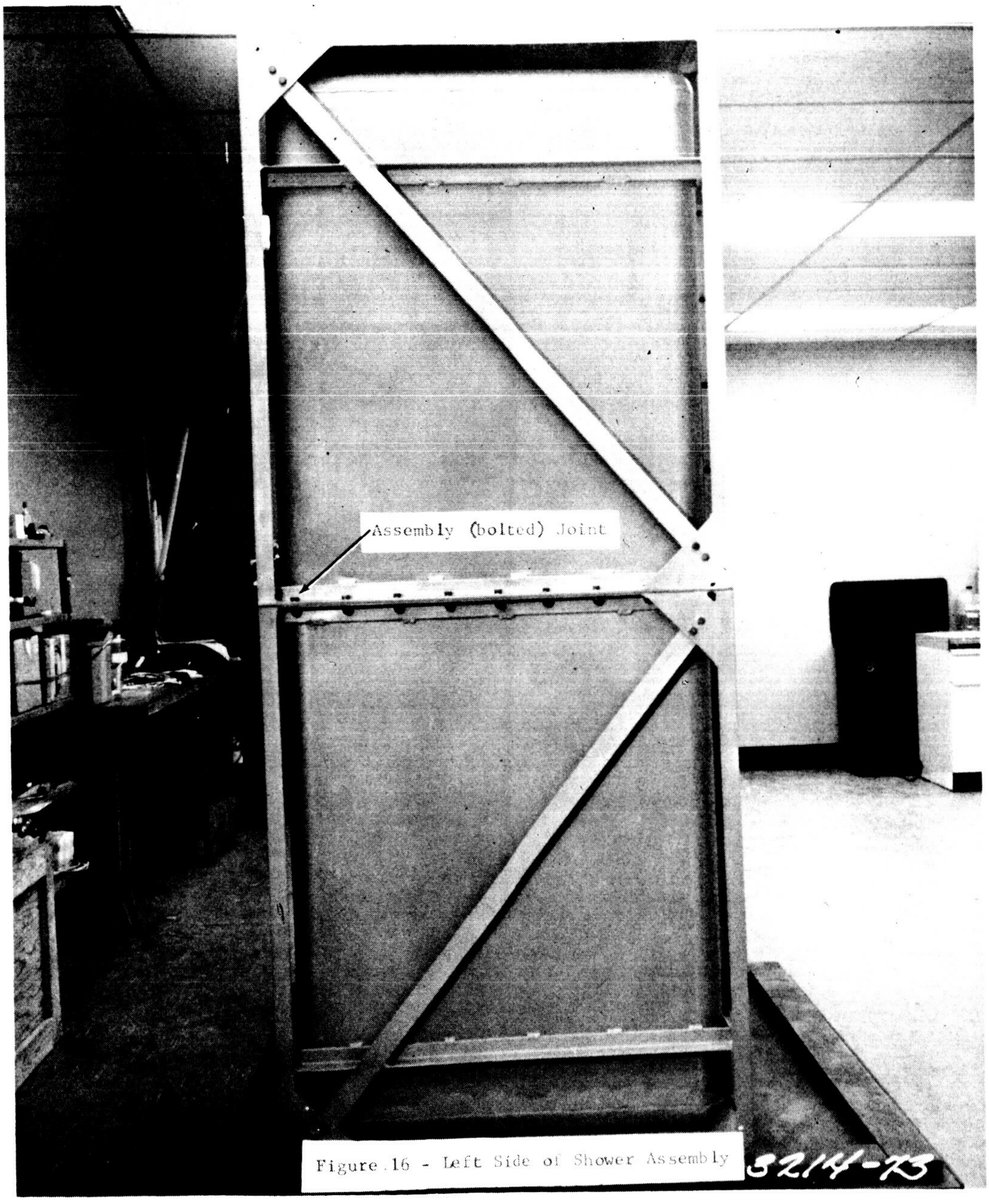


Figure 16 - Left Side of Shower

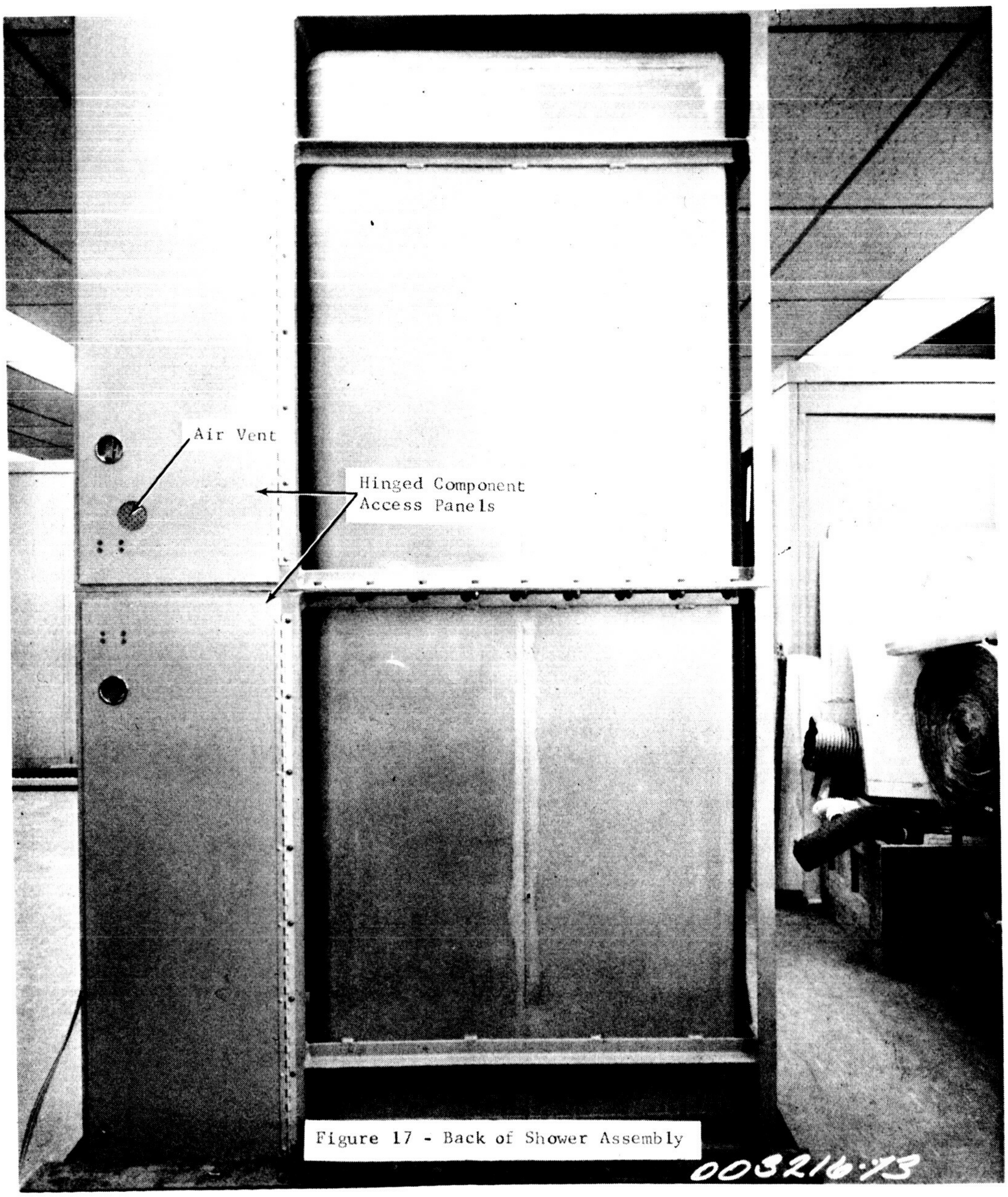


Figure 17 - Back of Shower

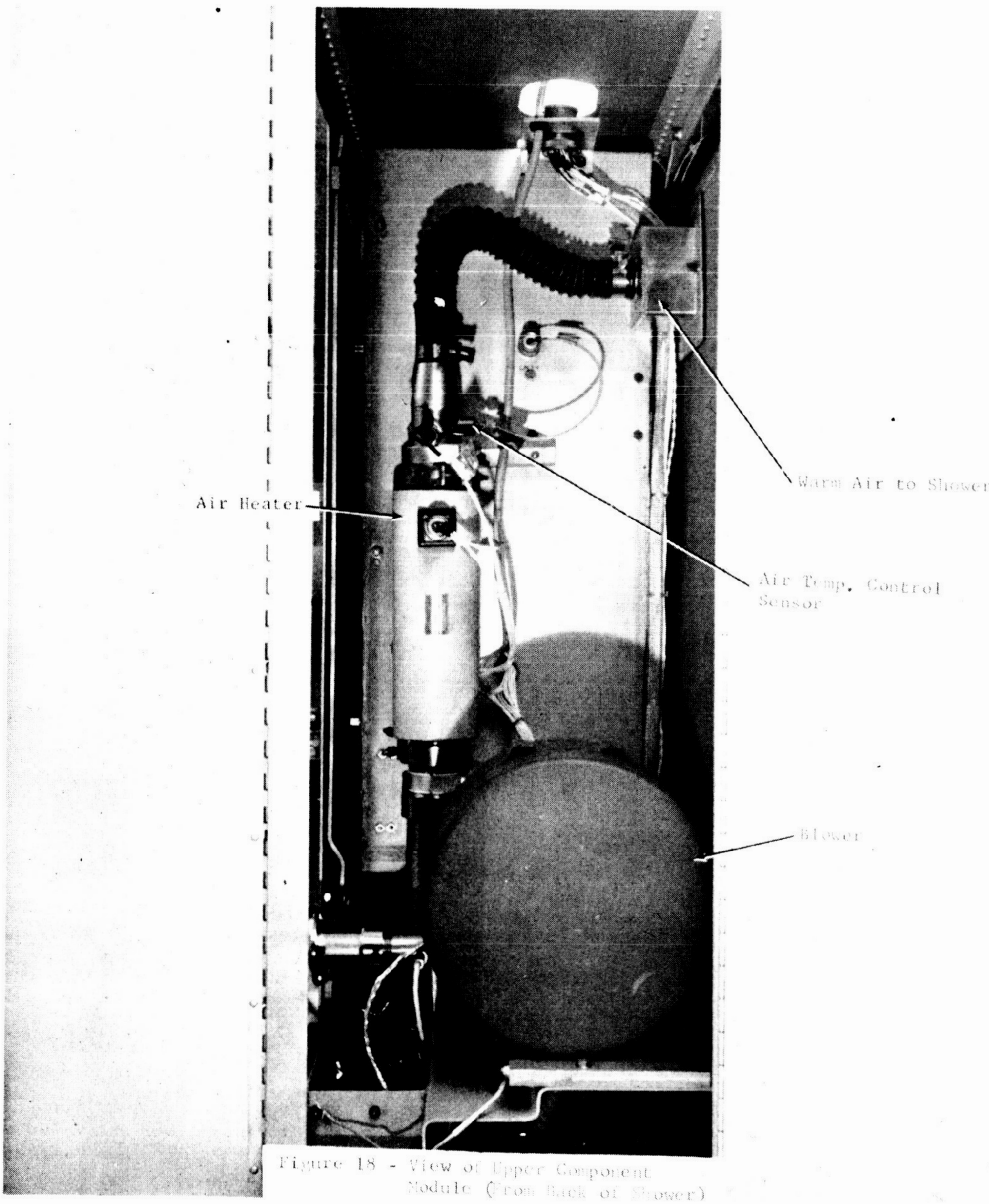


Figure 18 - View of Upper Component Module (From Back of Shower)

2.0 TASK 1 - CONCEPTUAL DESIGN

The objectives of Task 1 of this effort were twofold. First, clothes and dish washer/dryer concepts consistent with the water use model described in paragraph 1.1 were formulated. Water use and recycling schemes as applicable to the shower system design were investigated, as was the possible commonality of cleansing agents and sterilization techniques between the shower system and the clothes/dish washer/dryer schemes. The second phase of Task 1 included the preparation of conceptual designs for the various shower subsystems. Tests and analyses were conducted as necessary to define and compare the various concepts considered.

2.1 Clothes/Dishwasher and Dryer Concept Study

The clothes/dishwasher and dryer concept study was prepared by the Hamilton Standard Division of United Aircraft Corporation for Martin Marietta under subcontract number RC2-240004. The final report for their work is published in Volume II. The major conclusions of the study are:

1. Reusing wash and/or rinse water does not result in significent vehicle weight savings. The most attractive reuse approach is clothes rinse for clothes wash and dish rinse for dish wash which saves only 207 lbs. (93.89 kg) of vehicle equivalent weight. Of the 207 lbs. (93.89 kg), 138 lbs. (62.60 kg) are for electrical power savings and 62 lbs. (28.12 kg) are for heat rejection penalty. Only 7 lbs. (3.18 kg) are for hardware savings. The added degree of hardware complexity for cascading approaches probably outweighs the benefits of weight savings. Additionally, the relatively small weight savings are not significant.

2. For clothes washers the standard top loading mechanical oscillating agitator and fluidic agitator concepts and the front loading water drive spray concept impose essentially the same vehicle penalties and traded off the best of all the concepts. The water drive spray concept, however, is the most versatile when considered for combinations of washers and dryers. (See Fig 19)

3. For clothes dryers, it is generally concluded for minimum power and weight that drying times should be in excess of 10.8×10^3 sec. (three hours). The forced hot air electric dryer and the forced hot air dryer utilizing heat from thermal storage are the most practical competitive concepts. The forced cold dry air desiccant electrical heat regeneration is competitive weight-wise but is complex. The clothes line - forced convection and the clothes line - forced convection plus electric heat are the most weight competitive but require an excessively large vehicle volume. (See Fig 20, 21 & 22)

4. For combination clothes washer/dryers, there are nine competitive concepts that trade off within 160 lbs. (72.57 kg) of each other when the drying time is assumed to be at least 14.4×10^3 sec (four hours) (see Fig. 23)

5. A clothes-dishwasher-dryer combination has the potential of significant weight, volume and power savings for small increased hardware complexity. Either the water drive spray washer/forced hot air electric dryer or the water drive spray/forced hot air utilizing thermal storage, can be considered viable candidate concepts for a final SSP system concept.

6. The determination and commonality of cleaning agents and sterilization techniques for like hardware such as clothes washers and dishwashers can be the subject of another study. However, it is apparent that it should have no

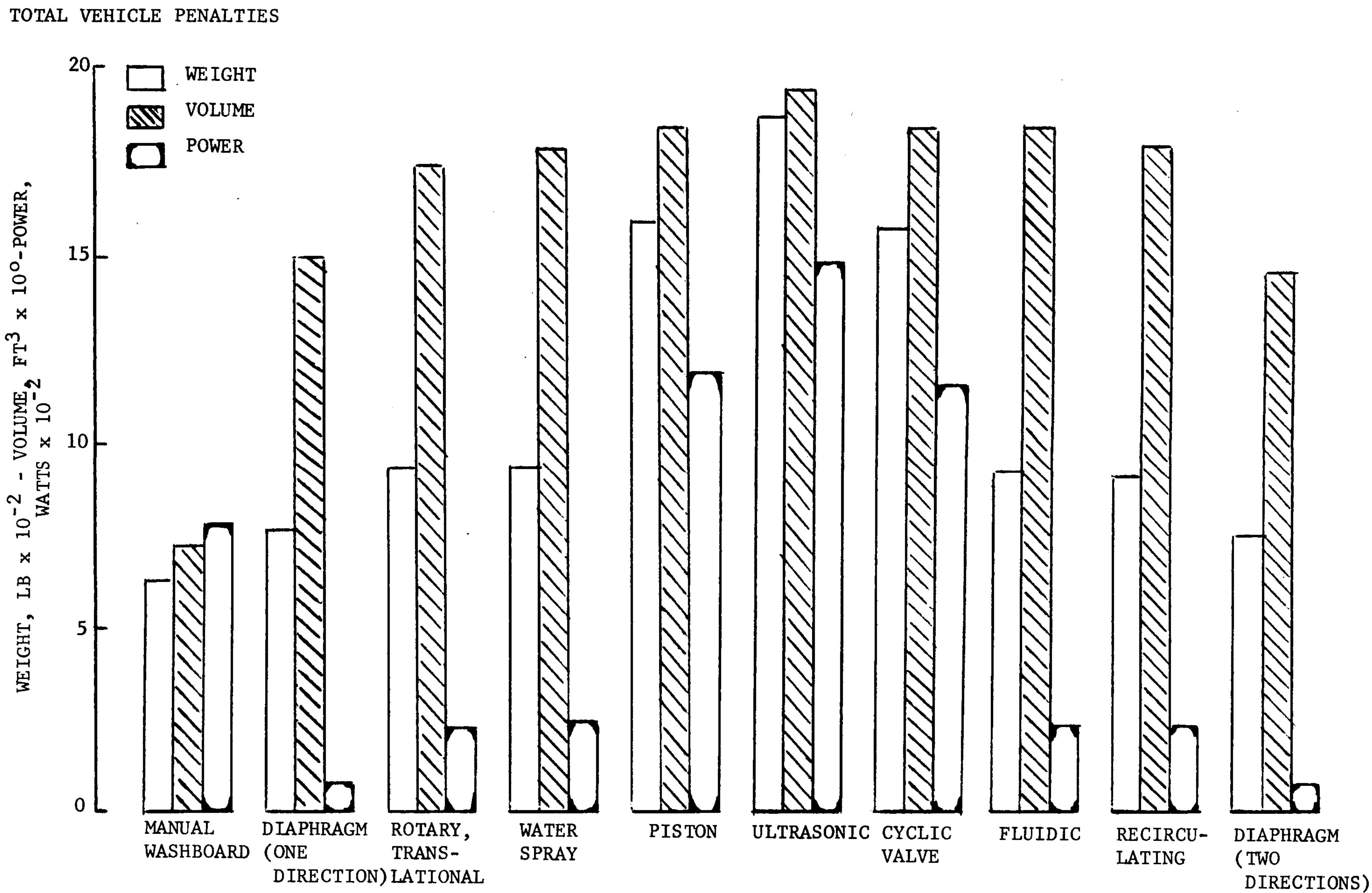


Figure 19 WASHER-TOTAL VEHICLE PENALTY COMPARISON

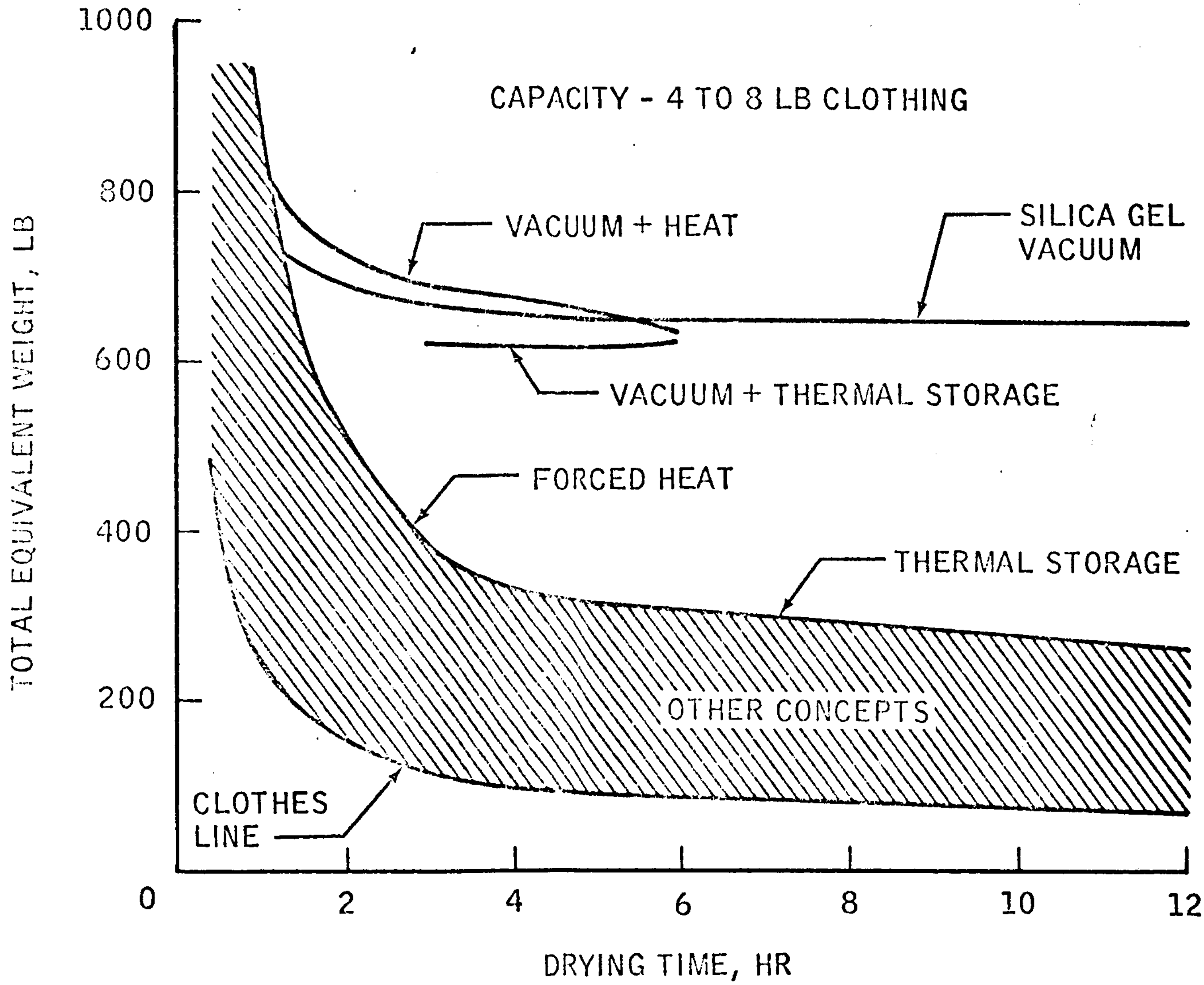


Figure 20 Dryer Weight as Related to Drying Time

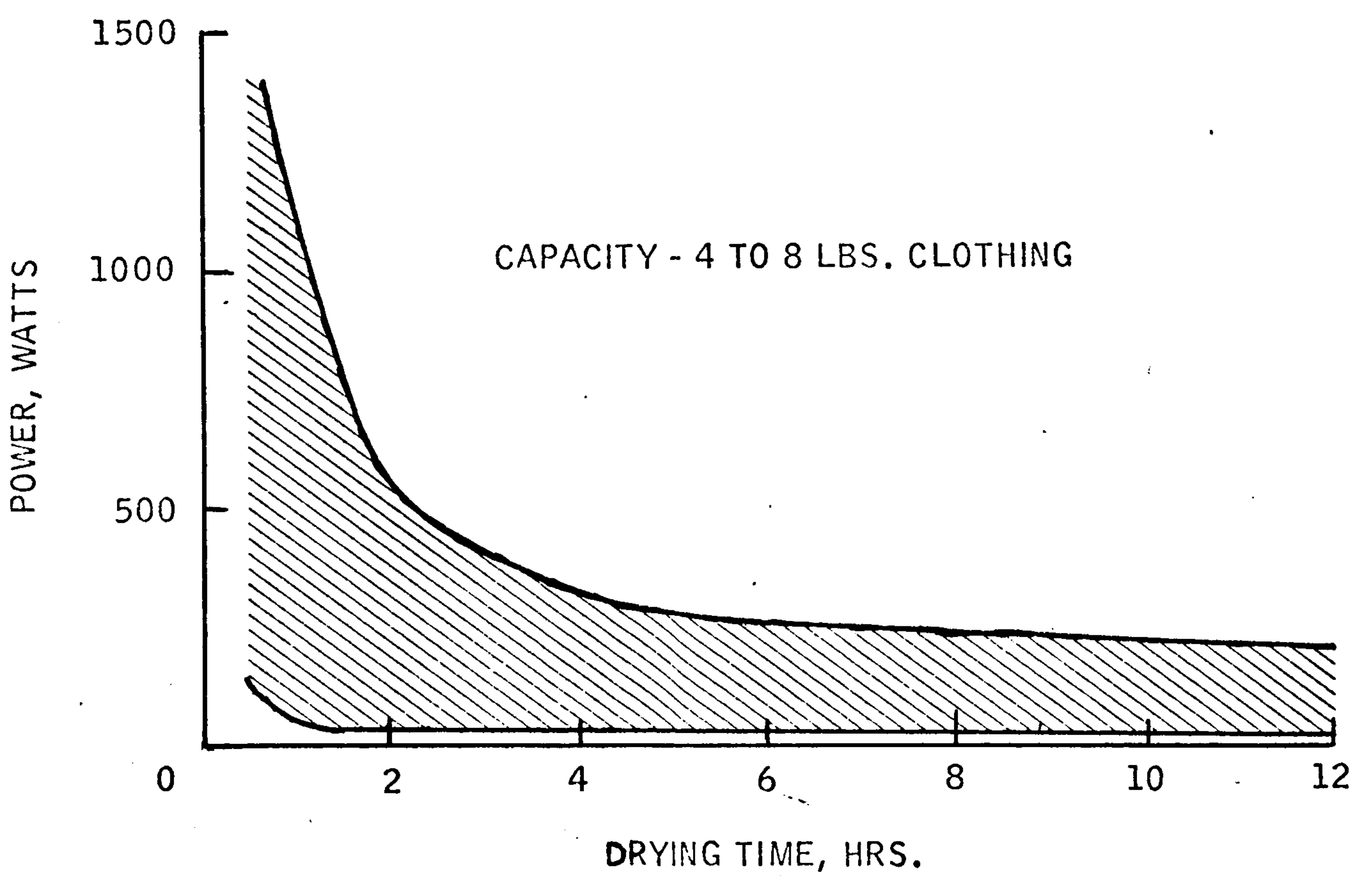


Figure 21 Dryer Power as Related to Drying Time

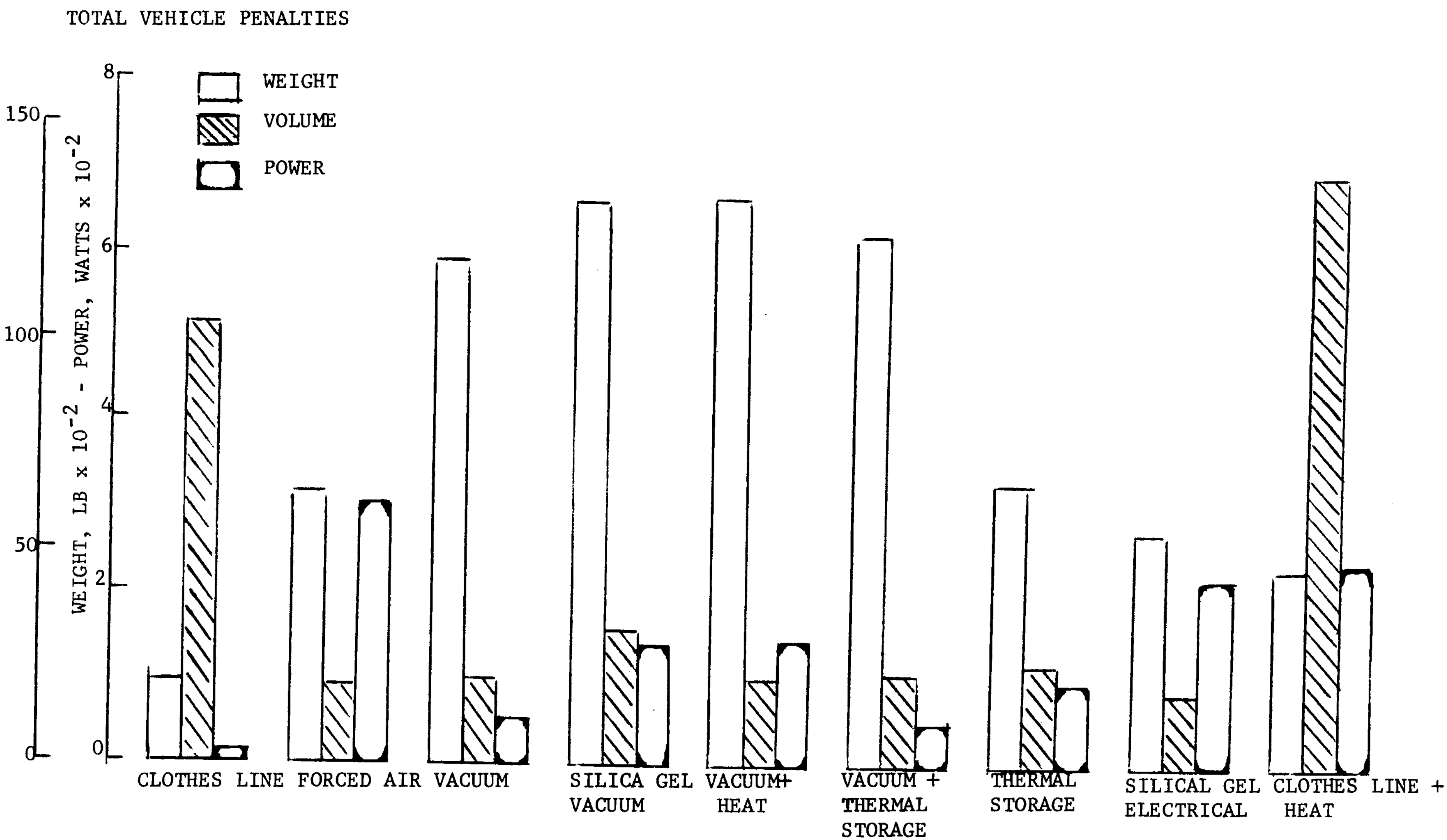


Figure 22 Dryer Concepts - Total Vehicle Penalty Comparison

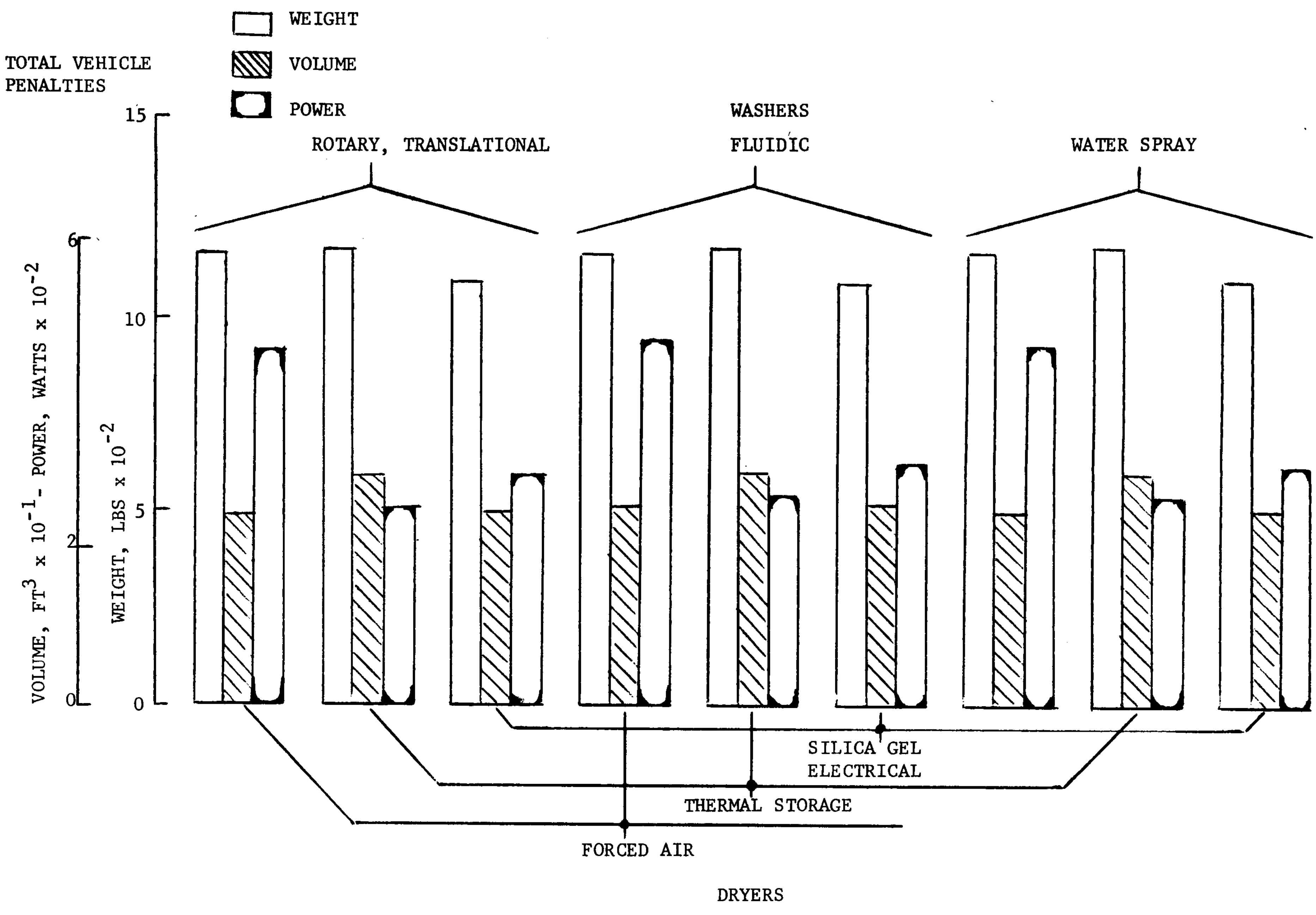


Figure 23 Washer/Dryer Combinations - Total Vehicle Penalty Comparison

influence on the results of this study since like concepts require essentially the same sterilization procedures and cleansing agents.

It is noted that there are three methods of sterilization: steam, hot water and bactericides. Steam sterilization will result in an excessively large weight penalty because a steam generator and condenser are required. Trapped water in lines may also result and be difficult to remove. The penalties associated with steam generation are briefly discussed in the dishwasher/dryer section. Both the hot water and bactericide method of sterilization are acceptable.

2.2 System Tradeoff Study/Concept Evaluations

Previous contract efforts by Martin Marietta (See NASA CR 112006) had determined that two principal methods of showering and drying were available. Vacuum pickup is the optimum concept for towel drying method and the air drag concept is optimum for the evaporation drying method. A series of tests and analyses were conducted to define these respective systems and to establish other system parameters.

2.2.1 System Tradeoff Study

This tradeoff analysis determined the better drying technique for removing water from the human body and the shower stall after showering. The two techniques to be considered are: (1) the vacuum pickup for the shower stall with towel drying of the body, and (2) the air drag system. Table 2 summarizes the results; the complete analyses are contained in Appendix A. The following requirements or assumptions have been established using the SSP and contract requirements:

1. The heat power penalty for heat added directly into the cabin cooling circuit is (8.35×10^{-2} kg/watt) .054 lbs/BTU/hr. The weight of extra valving and heat exchangers to tap into the cabin cooling circuit must be added.
2. The heat power penalty for heat added directly into the cabin is .074 lbs/Btu/hr for the cabin plus .054 lbs/BTU/hr for the cabin cooling circuit for a total of .128 lbs/Btu/hr.
3. The vehicle electrical power penalties are as follows:
   a. 591 lbs/kw for continuous DC power.
   b. 710 lbs/kw for continuous AC power.
   c. 270 lbs/kw for sunlit DC power.
   d. 351 lbs/kw for sunlit AC power.

Table 2 Shower System Tradeoff Analysis

Description and Components	Shower Concept	
	Vacuum Pickup	Air Drag
Operating Conditions	45 cfm at 10" water static pressure	470 cfm at 6" water static pressure
Condenser	Not required	Required including Heat Exchanger
Drying Technique	Towel plus 10 cfm bleed	Evaporation plus 10 cfm bleed
System Description	Closed loop	Closed loop
Shower Stall Temperature (Inlet)	$100^{o}F$ DB	$120^{o}F$ DB
Shower Power Concumption, watts (AC)		
Blower	88	549.9
Air Heaters	104	4705.6
Water Pump	57.5	57.5
Condenser Pump	--	57.5
Electronics	Neg.	Neg.
Total Watts	249.5	5370.5
SSP Equivalent Weight (lbs)	177	3814
Towel Wash/Drying		
Clothes Washer/Dryer Weight (lbs)	1104	--
Sensible/Latent Heat Loads		
Shower Bleed to Cabin (Btu/hr)	820	702
Shower Door to Cabin (Btu/hr)	372	271
Moisture Carried Out By Crewmen (Heat of vaporization)	264	264
	1456 Btu/hr	1237 Btu/hr
Total	2180 Btu/Day	1858 Btu/Day
SSP Equivalent Weight (lbs)	107.6 lbs	91.5 lbs
Condenser Load (Btu/hr)	None	14,965
SSP Equivalent Weight (lbs)	---	808
Total SSP Equivalent Weight (lbs)	1388.6	4713.5
Shower System Components		
Shower Stall Assembly (lbs.)	148	148
Components Module Assy (lbs.)	173	234
Instrumentation	36	36
	357	418
Total Spacecraft Weight for Shower System (lbs.)	1745.6	5131.5

4. The wash cycle usage rate is 110 lbs. consisting of 55 lbs. for washing and 55 lbs. for rinsing.
5. The wash size is estimated at approximately 4.0 lbs. (1.81 kg).
6. Spares weight is not included in this study.
7. It is assumed that effective spin drying from the washer concepts may be achieved and that a residual content of 1 lb (.454 kg) of water will be remaining in the six towels.
8. The crewman shall bathe, dry the whole body, and remove the water from the shower stall within 15 minutes. A total of six showering and drying operations per day in a one and one-half hour interval shall be performed.
9. Wash and dry cycle for the six towels is assumed to require five hours, one hour wash and 4 hours drying.
10. The heat power penalty for heat added directly into the cabin through the shower walls and when the shower door is opened after a shower is assumed equal for both concepts. Therefore, this penalty is included as a shower system penalty.
11. The total weight of the clothes washer/dryer is used as a weight penalty for the vacuum pickup concept. However, if the SSP requires a clothes washer/dryer for other purposes, the weight of the components, approximately 20% of the total weight penalty of the washer/dryer, should be subtracted from the vacuum pickup system weight penalty.

2.2.2 Concept Evaluations

Other tests conducted to verify sizing of the system blowers or to define other system parameters were completed

2.2.2.1 Water Pickup - The objective of this test was to help size the vacuum concept system blower, and determine the efficiency of vacuum pickup in a one-g environment: (a) the vacuum hose fully submerged in water, and (b) pulling a film of water off a surface.

Test equipment included a 90 CFM max, 50 in. water vacuum blower, LGS, Rotometer flow meter, 1-1/4 I.D. corrugated vacuum hose and water containers.

Data on air flow rates, initial water quantity, time to pick up water, and remaining water quantity (in container and/or hose) were recorded. See Table 3. The test results showed that:

- A minimum velocity of 51 ft/sec is needed to pickup water off of a one-g surface and retain it in the hose.
- Water was trapped in the hose under all test conditions and would drain from the hose after the blower was shut off. Note, this is because of the hose corrugations and a smooth hose or procedures to raise the hose head thus draining the water to the LGS must be initiated.
- With the vacuum hose submerged in 500g of water, pickup times of 3 to 5 seconds were recorded.
- Using the vacuum hose to pull 200g of water off a surface required 20-35 seconds.

Table 3 Water Pickup Test

1-1/4 ID Flexible Vac. Hose - Max Hose Height Above Floor: 38" No Pickup Head

Flow Rate (cfm)	Fully Submerged (water held in pan)			Surface Film Pickup (water spread on wide metal surface)			Remarks
	Initial Quantity (grams)	Time to Pickup* (sec)	Remainder (grams)	Initial Quantity (grams)	Time to Pickup* (sec)	Remainder (grams)	
18.5	500	1.2	75 in hose & pan	200	22	75	Water will not stay in hose when head is lifted off surface.
21.5		3.3	25 in hose & pan		36	30	
25.0		4.7	25 in hose & pan		23.5	50	
28.0		4.6	10 in hose only		33.6	20	Water will remain in hose although it will not completely clear.
29.0	500	3.7	5 in hose only	200	24	5	

*add 30 seconds to clear hose

2.2.2.2 Shower Air, Temperature & Humidity - The objective of the test was to determine the heat added to the air stream by the blower, shower warmup times, the temperature drop through the shower stall and humidity increases to verify contract statement of work requirements.

Test equipment included a vacuum blower, flow meter, shower stall and wet bulb/dry bulb thermometers.

Data on shower inlet and outlet dry bulb and wet bulb temperatures, wetting water quantity and temperature, and air flow rates were recorded, see Tables 4, 5, 6, & 7. Tests results determined that:

- The Rotron blower added significant heat to the air stream: avg of 44^{o}F per pass.
- There is considerable cooling of the air through the shower stall, note that the shower outlet temperatures are only a few degrees above ambient.
- Temperature and humidity can be raised to a comfortable range (77^{o}F DB 60% RH) by procedure within 5 minutes of blower startup.

As a result of these studies and tests it was concluded that the vacuum-pickup concept has the least impact upon SSP design; therefore, it was recommended for prototype design and the air-drag concept was eliminated from further consideration.

Table 4 Dry Bulb Temperatures at the Inlet and Outlet of the Shower Stall for a Fifteen-Minute Period

Test Condition Dry Air, No Moisture

% Meter Reading 48% ≈ 30 cfm No Bleed

Ambient DB 72 WB

Time (min.)

		0	1.0	2.5	5.0	7.5	10.0	12.5	15.0
Test #1	Inlet	72	94	104	114	120	125	127	129
Test #2	Inlet	88	113	112	127	130	131	132	133
Test #1	Outlet	72	72	74	76	77	78	78	79
Test #2	Outlet	73	76	77	78	79	79	80	80

Remarks: Ambient air

Consider Thermal Loss of Shower Stall to Cabin

Table 5 Temperatures at the Shower Inlet & Outlet of the Shower Stall for a Fifteen-Minute Time Period

Test Condition Closed Loop

% Meter Reading 48% $\approx$30 cfm

Ambient DB 72 WB 50

Time (min.)

		0	1.0	2.5	5.0	7.5	10.0	12.5	15.0
DB	Inlet	82	118	126	130	131	132	133	133
WB	Inlet		88	91	99	113	127	130	132
DB	Outlet	70	75	76	77	77	78	78	78
WB	Outlet		68	70	71	71	72	72	72

Remarks: Water @ 105°F spread on shower walls, floor, paper towels in air inlet for all humidity test runs.

Table 6 Temperatures at the Shower Inlet & Outlet of the Shower Stall for a Fifteen-Minute Time Period

Test Condition 400 grams H_2O at 105^oF

% Meter Reading 48% $\approx$ 30 cfm

Ambient DB 74 WB 49

Time (min.)

		0	1.0	2.5	5.0	7.5	10.0	12.5	15.0
DB	Inlet	100	114	122	126	129	130	132	132
WB	Inlet	70	80	89	89	91	108	120	126
DB	Outlet	69	71	74	75	76	76	77	77
WB	Outlet	62	66	70	71	72	73	74	74

Remarks: Dry bulb seems to dry out after 7.5 min.

Table 7 Temperatures at the Middle Portion of the Shower Stall with a Portable Relative Humidity Meter

Test Condition Moist Air

% Meter Reading 48% 30 cfm RH Meter in middle of stall

Ambient DB 7.15 WB 52

Time (min.)

		0	1.0	2.5	5.0	7.5	10.0	12.5	15.0
DB	Run #1	71.5	72	73	75	77	79	80	81
WB		52	56	62	67	69	70	71	71
DB	Run #2	73	72	74	77	80	80	82	83
WB		55	55	60	67	72	72	73	73

Remarks:

2.2.2.3 Bulk Liquid Soap Evaluation - Tests were performed to establish a method and design configuration to maintain pasteurization conditions in bulk liquid MIRANOL C2M-CONC and MIRANOL C2M-SF conc. soaps, and to dispense soap in prescribed amounts to the shower. The tests are described in Appendix B. From the tests it was found that strip type heaters can achieve desired temperatures but must be used indirectly and apply heat slowly (i.e. low wattage). It was also determined that temperatures greater than 145^{o}F produce adverse effects - primarily frothing and boiling. Testing related to soap delivery indicated it would be difficult to supply the soaps to the shower using conventional plumbing and controls. There was a persistant plugging problem and a 10 psig delivery pressure was insufficient. Problems encountered during these tests led to selecting an alternate method of soap dispensing and storage, prepackaged soap in small sealed bags.

2.2.2.4 Bleed Air Flow and Pressure Drop Analyses - The partially closed air recirculation loop utilized by the ZGWBS allows the CO_2 level in the shower stall to build up during its use to some point above ambient concentrations. To ensure that the maximum level reached during a 15-minute shower is not higher than 3.0 mm Hg (as identified in ZGWBS S.O.W.) for a given bleed flow rate, the CO_2 concentration at a specific CO_2 generation rate, system volume and CO_2 ambient level must be calculated. In order to minimize system weight, the lowest possible bleed rate necessary to maintain proper CO_2 levels must be sought.

Analyses of bleed rate requirements and total system pressure drops are in Appendix C. They show a 10 cfm bleed rate for the ZGWBS will be sufficient to insure that the CO_2 level will not exceed 3.0 mm Hg during a 15 minute shower.

In order to determine the operational characteristics of the blower utilized in the ZGWBS, the total system pressure drop must be determined. This system pressure loss in turn fixes the static pressure and, thus, the volumetric air flow rate at which the blower will operate. The static pressure versus air flow characteristics for the particular blower chosen for use are illustrated in Figure 24.

Superimposed upon the figure are the calculated pressure 5.86 in H_2O, and flow, 51 cfm, determined from the analysis described in Appendix C.

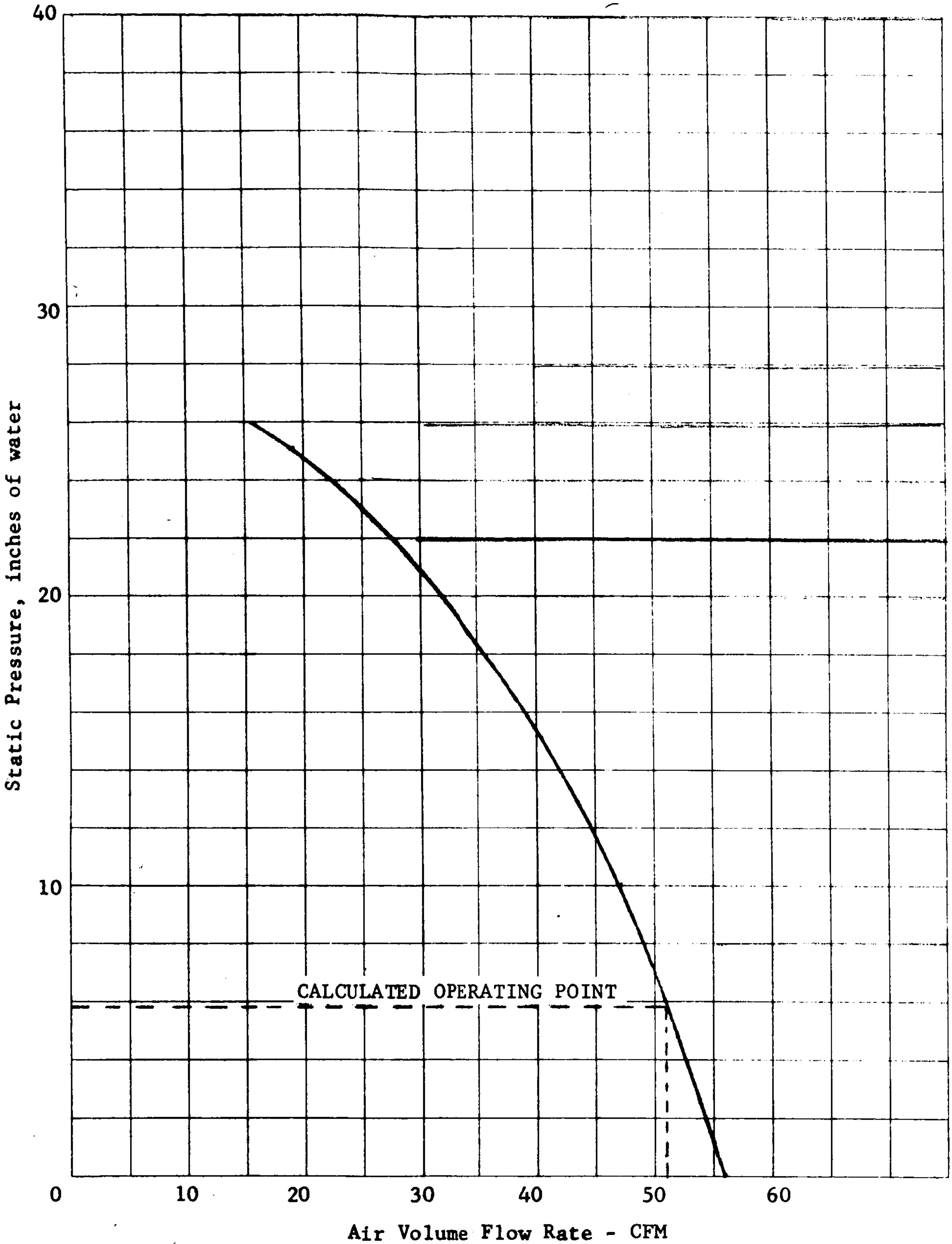


Figure 24 Static Pressure vs Flow Rate for Rotron Spiral SL2EA2 Blower

3.0 TASK 2 - PRELIMINARY AND FINAL DESIGN

Task 2 was divided into the preliminary and final design phases of the shower system. Since there was considerable evolution from the detailed preliminary design to the actual final design, only a brief description of some of the design alternatives considered for preliminary design will be presented here; the major emphasis is placed on the detailed final design of the shower.

3.1 Preliminary Design

3.1.1 Stall Configurations

Several factors were considered in determining the shower stall configuration. These considerations were (1) size for proper man/stall relationship, (2) ease of water collection, (3) minimum floor space and volume, (4) ease of cleaning and disinfecting after use, (5) satisfy modular construction requirement, and (6) ease of maintenance and repair.

The internal minimum dimensions of the shower stall were determined totally by the anthropometric data for the crewmen. The mission model requires that the shower be designed for a crewman six (6) feet high and weighing 190 pounds (maximum). Since these limits fall within the height and weight maximum for the 95th percentile man (as defined by the Bioastronautics Data Book), they must be used as the primary basis for defining stall dimensions. In addition to these measurements, clearance must be provided to allow the necessary motions required for body and hair wetting, scrubbing and rinsing operations, and to permit the movement required for drying of the body and cleanup of the stall. A foamcore mockup was fabricated and these required motions were measured by utilizing a 72-inch-tall subject weighing 195 pounds going through simulated showering motions, water collection, and cleaning and disinfecting after showering.

Table 8 indicates the design dimensions to allow adequate movement of the crewman to bathe all parts and areas of his body along with corresponding dimensions of a 95th percentile man.

Table 8 Shower Dimensions

	95th Percentile Man (in.)	Required Dimensions (in.)
Width at Shoulders	20.1	30.25
Height	72.0	79.5

The internal surfaces of the stall are TFE teflon coated (3 mils) to provide a smooth non-wetting surface that may be easily cleaned. In addition, a minimum of 2 inch radii are provided in all corners for cleaning ease and prevention of microorganism growth.

The floor of the stall has a rough surface to provide a non-slippery surface for use in one gravity. Foot restraints were designed for zero gravity use. The ceiling includes a polysulfone covering over the light assembly.

The top half of the door also includes a transparent section to provide additional light in the shower stall and also to prevent possible claustrophobia. The door closure is held by magnets along the door seal. This permits easy ingress/egress operations, does not interfere with showering operations, and provides for a smooth interior surface.

3.1.2 Water Distribution and Control Techniques

The two basic criteria that establish the amount of water used or wasted and the effectiveness of the shower itself are nozzle type and location. They determine the manner in which the water is sprayed on the subject during wetting and rinsing operations. Nozzle pattern pertains to the manner in which the water is dispersed and the corresponding spray angle. Figure 25 shows three

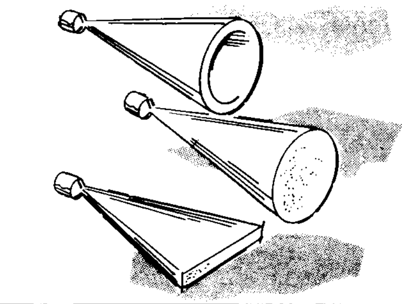
CONFIGURATION	NAME	DESCRIPTION
	Hollow Cone	Concentrated liquid at the outer edge.
	Solid Cone	Uniformly distributed spray pattern and optimum nozzle in test (Contract NAS1-9819) permits wetting over a uniform area quickly, with strong scrubbing action for rinsing.
	Flat Spray	Reasonably uniform droplet distribution narrow elliptical spray.

Figure 25 Spray Configurations

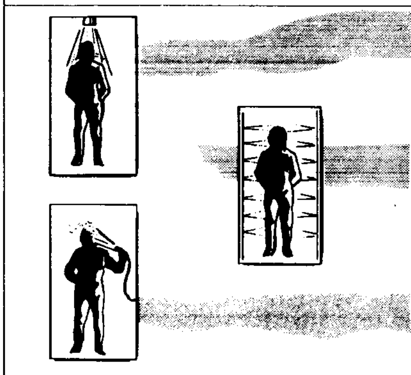
LOCATION	NAME	DESCRIPTION
	Fixed	Requires body to be continuously repositioned to wet skin, excessive water use.
	Manifold	Easily wets skin; difficult to rinse body folds; excessive water use.
	Hand-Held Movable	On/off thumb control; localized spray provides controlled wetting; controlled rinsing action of skin folds; minimum water usage.

Figure 26 Nozzle Locations

Table 9 Water Collection Techniques

SYSTEM	TECHNIQUE	ADVANTAGES	DISADVANTAGES
Air Drag	Use of Shear Flow Forces of a moving stream of air at 33 fps along a surface and 0.5 fps in a free volume.	Some evaporative drying if incoming air has low humidity. Good removal of air and H_2O without manual scraping by crewman.	Severe power penalties to achieve required air velocity along surfaces of stall and to heat air. Noise is uncomfortable.
Vacuum Pickup	Variation of Air Drag High-pressure vacuum-type blower to extract excess H_2O from walls with a flexible hose and a special H_2O pickup head.	Some evaporative drying if incoming air has low humidity. More positive water removal.	Requires manual scraping by crewman. Towel drying is necessary.
Evaporation	Evaporation and vaporization will occur when an unsaturated airstream comes in contact with water.	Crewman can dry from unsaturated airstream.	Low takeup by air; severe power penalties; excess moisture bled to cabin; addition of condenser to "dry" air. Time factor for drying is high.
Mechanical Scraper	A combination of a low airflow drag and use of a wall scraper to direct the H_2O to the stall. Two-phase outlet size at 33 fps.	Low power penalty. Efficient removal of water and air.	Added task required of crewmen.
Towels and Sponges	Utilization of capillary action of absorbent materials.	No readjustment to new drying technique.	Interface of this technique with an additional H_2O relocation unit. Possibility of microbial growth in these collection items. Requires additional expendables, hardware and power.

types of nozzle spray configurations. Spray angles to provide coverage (without overspray) of various body areas such as the arms have been investigated and reported in NASA CR-112006. A 25° cone angle was determined optimum. The minimum pressure necessary for a well-developed spray cone is 10 to 15 psi. Beyond this, pressure has a relatively minor effect on spray cone development. Nozzle location is best evaluated by comparing the capability of wetting and rinsing the skin with the amount of water utilized. Figure 26 shows three general nozzle locations. The solid cone spray with the hand held moveable nozzle concept has been designed into the shower system.

3.1.3 Water Collection Techniques

Techniques for water collection in a zero-g environment dictate the design of the SSP whole-body shower. These techniques utilize either airflow or mechanical devices to collect the surface tension-dominated water. Airflow techniques are air drag, vacuum, and evaporation. Mechanical devices include mechanical scrapers used in conjunction with a low airflow, towels, and sponges. The advantages and disadvantages of each of these techniques are described in Table 9 (NASA CR-112006) established that 33 fps was the necessary velocity to move water in a zero gravity environment. Since the SSP shower will be utilized in a one gravity test chamber, data in a one gravity environment was established as reported in monthly progress narrative no. 1 (MCR-72-69, Issue 1). The summary of the data was as follows:

- A minimum velocity of 51 ft/sec is needed to pickup water off of a one-g surface.
- Some water was trapped in the hose because of the hose corrugations. A smooth hose would prevent this problem.

3.1.1.4 Cleansing Agent Storage and Dispensing

The two techniques that were investigated included the following concepts:

1) Bladder storage tank, daily supply batch heater tank for sterilization, and pump dispenser.
2) 1080 (3/4" x 1" x 3-1/4") packages of pre-pasteurized soap that has no active growth of microorganisms. Storage in trays with a separate revolving tray for mechanical dispensing of one week's supply (42 packages).

Technique No. 1 requires a volume of approximately 3409 in^3, weighs approximately 30 pounds and utilizes approximately 55 watts of electrical power. Technique No. 2 requires a volume of approximately 4303 in^3, weighs approximately 20 pounds and utilizes no power.

Paragraphs 2.2.2.3 & Appendix B summarize testing accomplished in conjunction with technique no. 1 utilizing Miranol C2M. The complexity, reliability and maintainability of this system is summarized as follows:

- Pasteurization techniques are necessary as a crewman's hands come into contact with the dispensing device and microorganisms can be transmitted back to the storage tank.
- Achieving pasteurization requires close control of the heating process to prevent changing the characteristics of the cleansing agent.
- Check valves and other controls proved to be unreliable due to plugging with the relatively viscous Miranol C2M which tended to thicken and dry when in contact with air.
- Daily cleaning of the dispensing device was required.
- Daily requirement to activate the pasteurization process. This must be accomplished at a specific time so that the cleansing agent's temperature would be safe for contact by the crewman.

Technique No. 2 solves the shortcomings of technique no. 1 but does create additional packaging expendables. This does not appear to be a major problem, and therefore, technique no. 2 was selected as the baseline system.

3.1.5 SSP Integration Features

The interfaces between the shower system and the SSP which were integrated into the preliminary design along with SSP guidelines and criteria, are listed in the following paragraphs.

3.1.5.1 Fresh Water Delivered

Frequency/Crewman	1 day
Quantity (lbs/shower)	8.0
Delivered H_2O Temperature (^oF)	
Range	105 ± 5^oF
Delivered Flow Rate (lb/min)	5.0
Delivered H_2O Pressure (Psig)	25-32
Cleaning Agent	
Type	Castile Soap (Fisher Scientific 00-5-197) or Miranol C_2M (Miranol Chemical Corp.)
Concentration (% by weight)	0.1
Delivered H_2O Quality	
pH	6.0-8.0 at 25^oC (77^oF)
Total Solids	500 mg/liter
Taste & Odor	none at threshold Odor #3
Turbidity	11 units
Color, True	15 units
Total Organics	100 mg/liter, max

Particulate Size Range	No. of Particulates/ 500 ml Fluid
0-10 microns	unlimited
10-25 microns	1000
25-50 microns	200
50-100 microns	100
100-250 microns	10

Ionic Species

Aluminum	For reference only
Cadmium	0.01 mg/liter
Chloride	For reference only
Chromium (Hexavalent)	0.05 mg/liter
Copper	1.0 mg/liter
Iodide	For reference only
Iron	0.3 mg/liter
Lead	0.05 mg/liter
Magnesium	For reference only
Manganese	0.05 mg/liter
Mercury	0.005 mg/liter
Nickel	0.05 mg/liter
Potassium	For reference only
Selenium	0.05 mg/liter
Silica	For reference only
Silver	0.2 mg/liter
Zinc	5.0 mg/liter

Sterility

Free of viable organisms (organisms limited to bacteria, fungi, including molds and yeasts and algae and protozoa, either active of dormant) as determined by specific microbiological analysis.

3.1.5.2 Waste Water Returned

Flow Rate (ml/sec)	40.0 max

Water Pressure (psi)	Ambient (minimum)	
Typical Predicted Composition		
Solubles	lb/lb $H_2O \times 10^{-6}$	
Calcium	0.42	
Chloride	33.34	
Chromium (Hexavalent)	0.05	
Copper	1.00	
Iron	0.30	
Magnesium	0.42	
Manganese	0.05	
Nickel	0.05	
Potassium	12.47	
Silver	0.20	
Sodium	33.34	
Zinc	5.00	
Amino Acids	1.41	
Creatinine	0.83	
Glucose	2.08	
Lactic Acid	10.41	
Urea	14.58	
Uric Acid	0.29	
Detergent	1000.00	
Subtotal		1116.09
Insolubles		
Sebum	29.31	
Body Hair, Skin, Etc.	135.05	
Subtotal		164.36
Total Solids		1280.45

3.1.5.3 Vehicle Interfaces

Coolant

Fluid	H_2O	
	I	II
Flow (max) - (lbs/hr)	200	600
Inlet Temp. (max) (^{o}F)	40	60
Allowable Heat Rejection to cabin (max) (Btu/hr)	6000	6000
Inlet Pressure (Psig)	30-70	30-70
Allowable Latent Load Rejected to cabin (lb H_2O/hr)	0.8	
Number of Crew	6	
Duty Cycle Max usage in a 0.75 hour period	6	
CO_2 Production (lb/hr/man)	0.116	
Cabin Air Temperature (^{o}F)	65-75	
Cabin Dew Point (^{o}F)	46-57	
Size of Containers transferred between vehicle (inches)		
Cylindrical or rectangular (max)	40x40x50	
Spherical (max diameter)	40	
Height of operating equipment (max) (inches)	82	

3.1.5.4 Penalties

Electrical Power

Continuous regulated dc power (lb/kw)	591
Continuous regulated ac power (lb/kw)	710
Unregulated dc power on sunlit side (lb/kw)	154

Regulated dc power on sunlit side of Low earth orbit (lb/kw)	270
Regulated ac power on sunlit side of Low earth orbit (lb/kw)	351

Heat Rejection

Heat rejected directly to coolant (lb/Btu/hr)	0.054
Added increment for heat rejected to cabin air (lb/Btu/Hr)	0.074
Heat Addition weight penalty solar collector (lb/Btu/hr)	0.011

3.1.5.5 SSP Reliability Guidelines

- No single failure will compromise crew safefy
- No crew action will be required for an 8 hour period subsequent to a failure
- In addition to automatic fault detection monitoring and override features, automatic local shutdown must be provided for failures compromising crew safety.
- Each subsystem must be instrumented to permit performance monitoring by an interfacing onboard checkout system.
- Critical performance parameters are continuously monitored by the automatic fault detection system.
- Secondary equipment startup is performed by automatic fault detection system.
- Subsystem instrumentation must permit the automatic fault detection system to identify a malfunction to the lowest replacement unit (LRU)
- Subsystem LRU is the component or cartridge level.

3.1.5.6 Power and Safety

1. Power AC: 115 VAC, 400 Hz, 3Ø, 3 wire
   115 VAC, 60 Hz, 1Ø, 2 wire

2. Maximum ripple and transients:

Power	Transients	Ripple
AC	±200 volts peak 10 μsec, 10 pps	3 volts rms 50 Hz to 15 kHz
DC	±50 volts peak 10 μ sec, 10 pps	3 volts rms 50 Hz to 15 kHz
56 VDC	±100 volts peak 10 μ sec, 10 pps	3 volts rms 50 Hz to 15 kHz

3. Must survive ±50 VDC 10 milliseconds duration transient on 28 VDC
4. Safety ground for AC motors
5. No failure propagation
6. One megohm insulation resistance to ground

3.1.5.7 Automatic Fault Detection System Interface

1. Stimulus control signals are +5 VDC, 28 VDC and 2 to 28 VDC with accuracies of ±5% and maximum total current of 150 mv.
2. Signal outputs:

Measurement Type	Voltage	Frequency Duration	Accuracy
DC Voltage (Bipolar)	50 mv to 1 v	-	± (1% + 1 mv)
	1 v to 10 v	-	± (1% + 10 mv)
	10 v to 40 v	-	± (1% + 100 mv)
AC Voltage	50 mv to 1 v	50 Hz to 10kHz	± (1.5% + 3 mv)
	1 v to 10 v	50 Hz to 10kHz	± (1.5% + 30 mv)
Contact Closure	-	-	-
Frequency	50 mv to 40 v	0.1 Hz to 10kHz	±0.1% of value

3.1.5.8 Grounding and Isolation

1. Single point ground (SPG) system.
2. Primary power return isolated from chassis.
3. Secondary power and signal returns isolated from chassis.
4. DC power returns for each block box individually connected to SPG.
5. Stimulus signals return lines not connected to subsystem ground.
6. DC power uses DC-DC converters for isolation.

3.1.5.9 Design Guidelines

1. 0, 0.7, and 1 "G" flight design concepts.
2. All hardware maintainable in a flight manner.
3. Lowest replaceable components must be accessible without removing another component for maintenance as packaged.
4. Line drainage for maintenance not acceptable.
5. High REL items not required, especially where low REL alternates can be packaged in same volume.
6. Specific analyses for vibration, acceleration, and shock loads is not required in design except where they affect the concept directly.
7. Coatings may be used to minimize outgassing and fire safety problems.
8. Flight weight designs required only if concept or performance is affected.
9. Non-metallic materials acceptable per DNA-0002 and listed for each component or special procedures taken to hermetically encase components, or specifically test to determine fire safety and acceptable offgassing limits.
10. Human engineering requirements in accordance with MSFC-STD-267.

3.2 Final Design

The final design of the SSP Zero Gravity Whole Body Shower Assembly is given in Volume II to this report. This is the detailed drawing package for the ZGWBS; Figures 1-18 in this report give detailed views of the actual shower. A discussion of the design rationale for the shower, with references to Figures 1-18, follows.

3.2.1 Design Rationale

The exterior framework of the shower structure is primarily 1 1/2 inch aluminum angle (see Figures 1 and 16). This structure was utilized to ensure that the assembly could meet the 10g shipping requirement. A complete stress analysis was performed on the entire structure to insure satisfactory loading. This analysis (MCR-72-275) is presented in Appendix D. Stress plates were added at the top and bottom of the framework to distribute the forces across the entire cross-sectional area.

The assembly is composed of the stall itself and the upper and lower component modules, which contain the mechanical and electrical control equipment (Figures 1 and 6). The upper component module contains the air handling system and the electrical box (Figures 10 through 15 and 18); the lower module contains the waste water removal system and sufficient volume for the SSP inlet water temperature control assembly (Figures 7 - 9). The volume in the upper module, originally designed to contain the 180-day supply of cleansing agent packages, was not utilized since it was decided, after final design, that the SSP system would be responsible for the storage. The soap storage and dispenser design was retained, however, in drawings 89900000892 and 89900000896.

The complexity of the electrical component enclosure assembly evident in Figures 11-14 is due principally to the fault detection and isolation capabilities designed into the shower system (see paragraph 3.2.4). For example, the current sensors and transformers (Figure 12) provide signals for automatic fault detection. Most electrical connector terminations shown in Figure 11 are provided so that individual components can be removed separately. The electrical component support bracket shown in Figure 14 serves as both a mounting flange for the connectors and as a support for the flowmeter signal conditioners which protrude through the bracket.

The air handling system is shown in detail in Figure 15. Air flows from the blower outlet (past the bleed inlet) through the main air flowmeter and air heater, then into the shower stall itself. The bleed air inlet line also contains a flowmeter which monitors the flow maintained for CO_2 control. The heated air flows, before entering the stall, past two temperature sensors (Fig 10 & 18), one of which provides input to the temperature control unit and the other provides a signal for fault detection. Return air from the liquid/gas separator (LGS) air outlet flows past the bleed outlet orifice into the blower inlet.

Figure 7 shows the lower component module, which contains the liquid/gas separator (LGS) and other portions of the waste water removal system. The two phase air/water mixture enters the LGS from the vacuum pickup line. The water flows downward into the sump while the air returns back through the top center of the LGS. An air injection line from the blower assists LGS performance. The liquid level sensor detects water in the LGS sump and signals the water pump to activate. Water flows from the sump, (see Figure 9), through the filter and the SSP maintainable disconnect valves, through the pump and out the waste water line. Figure 8 shows the brackets which allows the LGS and the pump assemblies to be removed separately for maintanence.

Figures 3 and 4 show the shower stall interior, which is coated with Teflon S to facilitate water film pickup. The squeegee attached to the pickup head allows a scraping action along the stall surfaces. The length of the vacuum hose and the swivel at the wall interface allows easy coverage of the entire stall. A quick disconnect at the water hose/stall wall interface allows the hose assembly to be replaced easily. The handheld valve/water nozzle is shown in Figure 4, along with the soap packet holder, the Lexan cover over the fluorescent lights and the air inlet vent.

3.2.2 Non-Metallics Materials Summary

The Non-Metallic Materials Master Log is given in Appendix E, as updated to the final ZGWBS configuration. The principal non-metallic materials are the teflon coating in the stall, the polyurethane coating on the exterior shower structure, the Lexan 9030 LGS and stall door, and the silicone gasket material used in several locations. It should be noted that the teflon and polyurethane coatings were verbally approved by JSC, the Lexan was tested by the NASA materials test group and found to be satisfactory, and the gasket material was approved because in all cases it is used between metals or adjacent to a sufficient heat sink.

Most other non-metallics are associated with the commercial electronic components which are contained within individual metal housings and within the ZGWBS electrical box. Teflon coated wire was utilized throughout the system. In no specific case is a large (> 10 in^2) amount of untested, unknown or potentially hazardous material used.

3.3 SSP Interfaces

Prior to final design of the ZGWBS it was determined that the shower system would utilize only 220 VAC, 3Ø, 400 Hz power and would provide the SSP automatic fault detection with the required low-voltage input by using transformers where necessary or tapping the output of the given component. Table 10 shows the ZGWBS instrumentation list. The SSP/Shower Electrical Interfaces are given in Appendix F.

Mechanical interfaces are at two locations. The water temperature control assembly connects to the inlet of the ZGWBS water flow transmitter (3/8" CPV nut) (See Figure 7). The waste water line from the ZGWBS water pump interfaces with the SSP waste water system at the base of the lower component module. (See Figure 9).

3.2.4 FMEA/FDIA Summary

The Failure Modes and Effects Analysis (FMEA) and the Fault Detection and Isolation Analysis (FDIA) were performed by Hamilton Standard for Martin Marietta. These analyses are summarized in Volume II to this report. It should be noted that all potential failures related to the shower are categorized Criticality III since none affects crew safety. The logic tests which would be performed by the SSP automatic fault detection system to isolate a given failure are shown in the FDIA.

TABLE 10

ZERO GRAVITY SHOWER INSTRUMENTATION LIST

Instrumentation	Item No.	Test Point
Transformer	T1	Main Power Breaker Phase A Voltage Tap
Transformer	T2	Blower Switch Voltage Tap
Transformer	T3	Blower Phase A Voltage Tap
Transformer	T4	Heater Switch Voltage Tap
Transformer	T5	Heater Voltage Tap
Transformer	T6	Temp. Control Unit Voltage Tap
Transformer	T8	Liquid Level Sensor 3 Voltage Tap
Transformer	T9	Liquid Level Sensor 4 Voltage Tap
Transformer	T10	Liquid Level Sensor 2 Voltage Tap
Transformer	T11	Water Pump Phase A Voltage Tap
Transformer	T12	Circuit Breaker 3 Voltage Tap
Transformer	T13	Water Pump Phase B Voltage Tap
Transformer	T14	Water Pump Phase C Voltage Tap
Transformer	T15	Blower Phase B Voltage Tap
Transformer	T16	Blower Phase C Voltage Tap
Transformer	T17	Main Power Breaker Phase C Voltage Tap
Transformer	T18	Main Power Breaker Phase B Voltage Tap
Current Sensor	CS1	Blower Phase A Current Monitor
Current Sensor	CS2	Water Pump Phase A Current Monitor
Current Sensor	CS3	Liquid Level Sensor 1 Current Monitor
Mass Flowmeter	FM2-SC1	Main Air Flow Rate
Mass Flowmeter	FM3-SC2	Bleed Air Flow Rate
Resistance Temp. Sensor	TA	Main Air Temperature
Temp Control Unit Thermocouple	TCU-TC	Main Air Temperature

4.0 TASK 3 - FABRICATION AND TESTING

In Task 3 the final design of the shower assembly was fabricated and extensively tested to ensure its satisfactory performance. Volume II to this report contains the complete drawing configuration of the shower and Figures 1-18 herein show the actual shower system as delivered to JSC.

4.1 Fabrication

Subsequent to the critical design review, fabrication of the ZGWBS was begun. The shower framework and structure, along with subassembly brackets, mounting plates and the electrical component enclosure, were fabricated in the Engineering Model Shop. After teflon coating of the shower stall interior was completed by an outside vendor, the exterior shower structure was coated with clear polyurethane to enhance the wear characteristics of the bare aluminum.

Electrical subassemblies were wired as hardware items became available after receipt/acceptance by quality and program personnel. Several items had to be returned to the vendor because of damage in shipment or nonconformance to procurement specifications. For example, the watthour meter was returned because of damage evident upon program receipt and the watthour counter was originally rejected because of a 60 Hz instead of a 400 Hz unit was delivered. The water totalizer was also returned to the vendor because of an internal grounding problem. All such nonconformances were corrected before the individual units were assembled into the shower.

Mechanical subsystems were assembled into the ZGWBS and the air flow from the blower was adjusted to the proper range by sizing the orifice plates on the bleed in and out ports. Performance checks of the vacuum pickup system were conducted and the operational status of the entire assembly was verified.

During the check-out of the vacuum pickup, liquid/gas separator and water pump systems, hair, lint and other debris collected by the pickup system accumulated to the point where the operation of the water pump was seriously degraded. At one point the main teflon gear in the pump failed entirely (see Figure 27) and the pump was returned to the vendor for repair. Investigations showed that the debris fouled the gear and broke one of the gear teeth. A replacement was immediately used to make the pump operational and an in-line flow through filter was placed at the pump inlet to prevent further pump damage (see paragraph 4.2.2).

4.2 Testing

A detailed report of the testing performed on the ZGWBS is given in Test Report, SSP Zero Gravity Whole Body Shower MCR-73-168, June 1973, included in Volume II. A summary of that testing is given in the following paragraphs.

Three types of tests were conducted on the shower assembly. Functional tests were performed to check the integrity of the shower subsystems and to insure that all parts operated properly. A 10-day performance and demonstration test determined the capability of the shower system to provide maximum shower usage (6 showers in 1.5 hrs./day) and to distribute and retrieve the water properly. The performance test also included a performance map of the following personal comfort parameters: air temperature (in stall), relative humidity (in stall), CO_2 level (in stall) and noise level (inside and outside stall). The third type of test conducted on the shower assembly was a microbiological assay of the stall interior to detect microbial growth. These tests were conducted in conjunction with the 10-day demonstration tests.

Figure 27 Water Pump Gear Damage

4.2.1 Functional Test Summary

Functional tests on the zero-g shower were conducted according to the procedure outlined in Appendix I of the test report. (See Vol. II) It should be noted that several minor deviations from the original procedure occurred during the test and these were noted in the test data. For example, the functional tests were conducted without the liquid level sensors in place. In addition, the water transmitter/totalizer was found, before test, to be insensitive to low flow rates ($<$ 1 gpm) and, since the nominal flow in the shower is 0.3 gpm, the water transmitter/totalizer was not utilized in any of the shower system tests.

All values checked during the functional test were entirely nominal except for two transformers with output to the SSP automatic fault detection system. These transformers did not indicate any voltage output and were considered failures; spares were utilized to replace the failed units, were subsequently tested and gave the proper voltage during operation.

The failed transformers were later rechecked after they had been removed from the shower system and were found to be operating properly. The units were then returned to the vendor to determine the cause of this intermittent failure. The vendor (Abbott Transistor Laboratories, Inc.) checked the units for possible open windings, turns ratio and rated secondary voltage. Vendor conclusions based on those tests were:

> "One unit appeared to be good electrically although there were solder voids in some of the terminals. The other unit provided less than the specified secondary voltage and there were solder voids in some of the terminals of this unit also.
>
> It is our analysis that the intermittent failure is most likely the result of insufficient solder in the terminals, probably caused by the inadvertent application of excessive heat during soldering."

All seventeen transformers in the shower assembly were rechecked and all gave the proper output voltage during operation. It is concluded that the failures which occurred were due to improper installation, and that those failures were isolated incidents which would not occur again. Table 11 as reproduced from the test report, gives the data obtained during the functional tests.

4.2.2 Performance and Demonstration Test Summary

The performance and demonstration tests on the zero-g shower were actually five separate tests conducted in conjunction with each other. The major portion of the performance and demonstration tests was the ten-day test in which six showers were taken each day to evaluate shower performance over an extended period. In addition, noise levels inside the shower stall and outside the shower assembly were measured, carbon dioxide (CO_2) buildup and relative humidity levels during a shower operation were monitored, microbiological assays were taken at several intervals during the ten-day test, and finally, a separate one-day demonstration test was performed utilizing the 89900000851-019 Assy blower (Rotron) and the revised liquid level sensing system. The results of each test are summarized below:

4.2.2.1 Ten-Day Demonstration Test -

The ten-day test of the shower system consisted of having six subjects each take one shower a day for ten days. The tests were performed using the 89900000851-009 Assy (Hamilton Standard SSP Blower) which had been previously determined to exceed the noise specifications required. The levels were high enough to warrant using ear plugs during the tests (both subjects and test personnel, see paragraph 4.2.2.2)

TABLE 11 FUNCTIONAL TEST - ZGWBS

Procedure Line No.	Parameter Tested	Operational Condition/ Test Criteria	Item Status	Failure/ Type	Corrective Action	Retest
2	Time Meter Watthr Meter Water Totalizer	Reading Only	Time 9.4 HRS. Watthrs 2318 Water 0 GAL.			
3	Flowmeters	Operational Check	Main Air Flow 31 SCFM Bleed Air Flow 4.8			
4	Blower	Observation				
7	Air HTR/TCU	TCU Dialed Temp. vs. Indicated Temp. Air Stream Temp.	Dialed Temp. 125 °F Indicated Temp 125 °F Air Vent Inlet Temp. 122 °F			
8	Light	Operational Check	Good			
9	Water System/ Valve Nozzle	Operational Check				
10	Vacuum Pickup	Operational Check				
11	Liquid Level Sensors	Operational Check				
	Water Pump	Pump On @ High LLS, Off @ Low LLS Visual Leak Check				
12	Pump Override Switch	Operational Check				
13	Liquid/Gas Separator	Visual Check	Good			

TABLE 11 FUNCTIONAL TEST - ZGWBS

Test Conducter J.A. Lenda Date: 5/6/73

Test Conducter L. [illegible] Date: 5/6/73

TABLE 11 FUNCTIONAL TEST - ZGWBS

Procedure Line No.	Parameter Tested	Operational Condition/ Test Criteria	Item Status	Failure/ Type	Corrective Action
14	Timer	Timer Reading Vs. Observed Blower Operating Time	Timer Reading 1: 9.8 Timer Reading 2: 10 2-1= .2 Blower Operating Time 12 Min. (Independent Meas)		
15	CB6 OFF	Water Pump Inoperative	Good		
16	CB5 OFF & CB4	Blower & HTR Inoperative Voltage At (=zero) @ Pins A & B			
17	CB4 OFF	TCU inoperative			
18	CB2 OFF	Controls & Light Inoperative			
19	CB2 OFF	Air Flowmeters Inoperative	Good		
20	Watthr Meter	Watthr Meter Reading vs. calculated Power Usage	Watthr Meter 1: 2480 Watthr Meter 2: 2494 2-1= 14 Watt hrs Cal. Pwr Usage 1-2= 13 Watt Hrs		

TABLE 11 FUNCTIONAL TEST - ZGWBS

Test Conducter: J. A. Lenda Date: 5/6/73

Test Conducter: [illegible] Date: 5/6/73

TABLE 11 FUNCTIONAL TEST - ZGWBS

Procedure Line No.	Parameter Tested	Operational Condition/ Test Criteria	Item Status	Failure/ Type	Corrective Action	
21	Water Transmitter/ Totalizer	Water Flow Rate and Quantity vs. Calculated Values	Totalizer 1:____ Totalizer 2:____ 2-1=____ Time 2-1=____ Calculated Flow Rate:____ Measured Water Quantity 2-1=____	Not Utilized		
22	TCU, Heater, Temp. Sensor, Calib. Curves	Air Temp. @ Stall Inlet vs. TCU Indicated Temp; Voltage @CN11, E & F, TCU Calib. Curve Temp. Resistance @CN11 S, T&U, Sensor Calib. Curve Temp.	Stall Temp. 127 °F TCU Temp. 125 °F CN11, E-F 2.1 VDC TCU Curve Temp 123 °F CN11, S, T&U 242 OHMS Sensor Curve Temp. 128 °F			
23	Air Flow Rates (Main)	Measured Main Flow vs. Flowmeter Reading Voltage @CN11, B&C vs. Calib. Curve Flow	Main Flow 28 SCFM Flowmeter 31 SCFM CN11, B & C 3.3 VDC Calib. Curve Flow 32 CFM			
24	Air Flow Rates (Bleed)	Measured Bleed Flow vs. Flowmeter Reading, Voltage @CN11, GG&HH vs. Calib. Curve Flow	Bleed Flow 4.1 SCFM Flowmeter 4.7 SCFM CN11, GG&HH 2.96 VDC Calib. Curve Flow 5 CFM			

TABLE 11 FUNCTIONAL TEST - ZGWBS

Test Conducter: J. A. Lenda Date: 5/6/73

Qual Assurance [illegible] Date: 5/6/73

TABLE 11 FUNCTIONAL TEST - ZGWBS

Procedure Line No.	Parameter Tested	Operational Condition/ Test Criteria	Item Status	Failure/ Type	Corrective Action	
25	Transformers(5 vac):					
	CB1, Trans. 1	Voltage @ CN 11, Y-Z	5.5 VAC			
	CB1, Trans. 17	Voltage @ CN 11, k-n	5.5 VAC			
	CB1, Trans. 7	Voltage @ CN 11, W-X	5.5 VAC			
	Blower Switch Trans. 2	Voltage @ CN 11, a-b	5.5 VAC			
	Blower Relays					
	Trans. 3	Voltage @CN 11, c-d	5.4 VAC			
	Trans. 15	Voltage @CN 11, CC-DD	5.4 VAC			
	Trans. 16	Voltage @CN 11, EE-FF	5.4 VAC	Initial Reading Zero	Transformer Replaced	
	Heater Switch Trans. 4	Voltage @CN 11, e-f	5.5 VAC			
	Heater, Trans. 5	Voltage @CN 11, g-h	5.5 VAC			
	TCU, Trans. 6	Voltage @CN 11, i-j	5.5 VAC			
	Liquid Level Sensors					
	Trans. 8	Voltage @CN 11, n-p	5.6 VAC			
	Trans. 9	Voltage @CN 11, q-r	5.4 VAC	Initial Reading Zero	Trans., Replaced	
	Trans. 10	Voltage @CN 11, s-t	5.6 VAC			
	Water Pump,					
	Trans. 11	Voltage @CN 11, u-v	5.47 VAC			
	Trans. 13	Voltage @CN11, y-z	5.5 VAC			
	Trans. 14	Voltage @CN 11, AA-BB	5.5 VAC			
	Light & Controls Trans. 12	Voltage @CN11 w-x	5.5 VAC			

TABLE 11 FUNCTIONAL TEST - ZGWBS

Test Conductor J. A. Lenda Date: 5/6/73

Test Conductor L. J. Leski Date: 5/6/73

TABLE 11 FUNCTIONAL TEST - ZGWBS

Procedure Line No.	Parameter Tested	Operational Condition/ Test Criteria	Item Status	Failure/ Type	Corrective Action
26	Current Sensors Voltage Vs. Calib. Curve Current:				
	CS1, Blower (Phase A	Voltage @CN 11, H-J, Calib Curve Current	.748 VDC .748 AMPS		
	CS2, Water Pump (phase A)	Voltage @CN 11, L-M, Calib. Curve Current	.2 VDC .2 AMPS		
	CS3, LLS1	Voltage @CN 11, P-R, Calib Curve Current	.2 VDC .2 AMPS		
27	CB1 OFF	ZGWBS Inoperative	Good		
29	Panel/Fastener Assys	Performance Check, Visual	Good		

TABLE 11 FUNCTIONAL TEST - ZGWBS

Test Conductor J. A. Lenda Date: 5/6/73

Qual Assurance [illegible] Date: 5/6/73

In addition, the liquid level sensing (LLS) system was not utilized during the ten-day test, except for Day 5 when the revised system was utilized for that day's six showers. As an alternate to the automatic sensing system, the manual pump override switch was activated by the test conductor as needed during the showering operations.

An additional one-day demonstration test was conducted several weeks later to verify the performance of the 89900000851-019 Assy. using the Rotron blower and the revised LLS system. Performance data from that test are included in this summary. (For a summary of the separate one-day test see paragraph 4.2.2.3.)

The data recorded during the demonstration tests are included in the test report but are too extensive to include here. A separate data sheet was provided for each test subject and each shower, a total of 67 showers were taken during this test phase.

Subjects were allowed to select the air temperature which they considered most comfortable on a personal basis. Water temperature was set at 100-110^{o}F through all showers. Subjects were instructed to go through a normal showering and cleanup procedure, and were advised that they should use as much water and take as much time as they felt necessary. They were also allowed to make their own choice as to hair washing in each shower. All showers except two were taken with Miranol Jem cleansing agent; in the two exceptions, (one during the special one-day demonstration test) Neutrogena was utilized.

All shower systems functioned satisfactorily throughout the ten-day test period. One anomaly which was noted in the early stages of the test was quickly analyzed and corrected. The anomaly was related to the use of the pump override switch and a filter element located at the liquid gas separator (LGS) sump outlet. During fabrication it was determined that a simple flow-through filter should be placed between the LGS water sump outlet and the water pump inlet to protect the pump from hair, lint and other particulate matter which might impair pump performance. During the early test, this filter was allowed to remain in place until it became increasingly clogged with foreign matter, thus reducing drastically the water flow into the pump. This decreased water flow caused a corresponding increase in the running current of the pump, which caused a total current load sufficient to trip the circuit breaker (CB5) on the blower/pump override line.

Ordinarily, such a current overload would not occur since the nominal mode of operation is to use the liquid level sensor (LLS) pump circuit, which operates through a different circuit breaker (CB6) than the blower circuit breaker (CB5). When the pump override switch, which operates on a circuit independent of the LLS circuit (CB5 vs. CB6), is utilized the blower would under normal procedures be OFF. Since the LLS system was not utilized during most of the demonstration tests, normal procedures were waived and the pump override switch was used while the blower was also operating.

With a clean filter, the combined current loads of the blower and water pump were nominally within the trip limit of circuit breaker 5. As the filter became clogged, however, the increased current load on the pump was sufficient to overload the circuit and trip the breaker. It was determined that the filter should be thoroughly cleaned after every three showers to prevent current overload. This procedure was followed throughout the rest of the test period and no further problems were experienced after Day 1. Several qualitative data points were obtained during these tests which deserve mention. The packages of Neutrogena cleansing agent which were to be utilized during the showers were an aluminized mylar material with a corner notched for easy opening. It was noted, however, that if the subject's hands were wet the package became difficult to tear open. If such packages are used extensively, a procedural note should be added to open the packages before wetting the hands.

After several days of showering without cleaning the stall (as per procedure), relatively large quantities of hair were evident on the vacuum pickup head screen and on the stall floor. Figure 28 shows the approximate configuration and type of buildup of hair on the stall floor. Daily cleaning of the stall floor and pickup head screen by hand would avoid gross buildup of such contaminants. Figure 29 shows the type of contaminats collected by the flow - through filter located at the base of the liquid/gas separator sump just upstream of the water pump inlet. The quantity of hair, lint and other contaminants evident during testing are not surprising and present no difficulties in themselves.

Table 12 below gives a summary of the data obtained from the sixty (60) showers taken during the ten-day test and the seven showers taken during the one-day demonstration of the Rotron blower and LLS system. The water distribution system (hand-held valve and nozzle) and LGS assembly operated very well throughout the tests. Although occasional slugging in the vacuum pickup hose was noted due to marginal air flow, this system operated satisfactorily in the one-gravity situation.

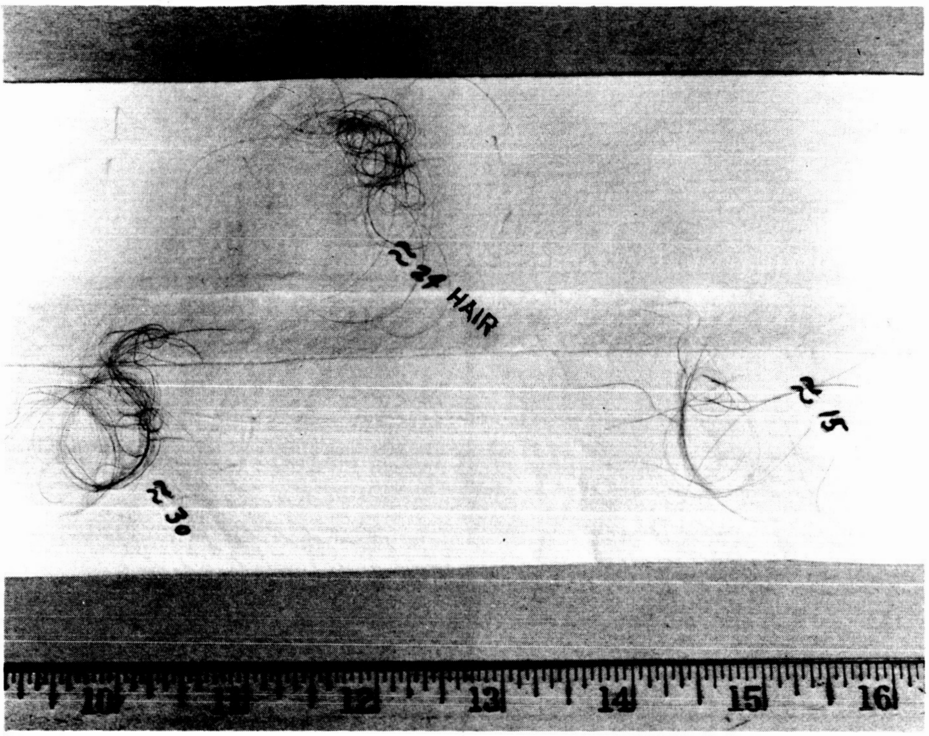
Table 12 Demonstration Test - Summary - 67 Showers

Parameter	Total	Avg/Shower
Time (Min.)	646.3	9.7
Power (Watthr)*	3584	59.7
Water (ML/Gal)	166815/44.1	2490/.66

* Days 1 - 10 Only

Figure 27 Water Pump Gear Damage

Figure 28 Hair Buildup on Shower Stall Floor



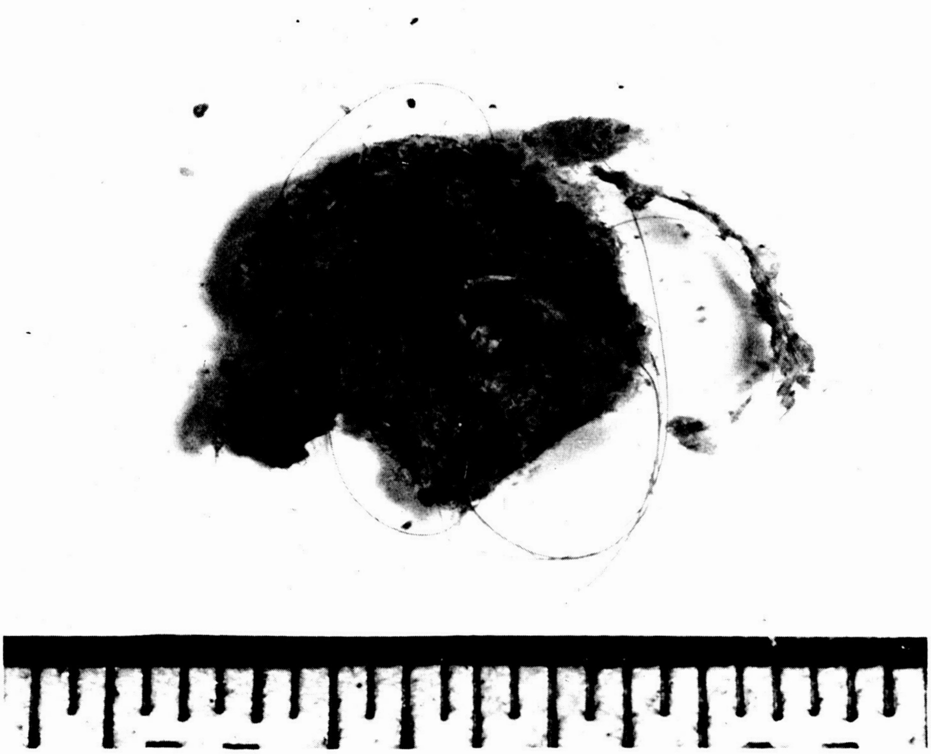


Figure 29 Contaminant Collected by Filter-Six Showers

Table 13 Subject Summary - Demonstration Tests

Subject	Approx. Height Percentile	# Showers	Hair Washed/ Not Washed	Avg. Water/ Shower (Gal)	Avg. Pwr/ Shwr (Watt hr)	Ave. Time/ Shwr (min)
John L.	80	10	3/7	.35	53.3	7.6
RP	99	8	6/2	.67	79.7	13.2
DB	50	7	4/3	1.11	82.3	13.4
MH	40	7	0/7	.83	58.1	8.0
TL	70	7	1/6	.37	44.1	8.8
RC	50	5	1/4	.73	47.0	8.9
TJ	40	5	5/0	.69	53.3	9.3
CC	60	5	4/1	.55	50.3	7.8
DG	95	3	0/3	.51	58.0	8.6
PG	85	3	3/0	.81	70.0	9.7
ES	75	2	1/1	.81	58.5	10.3
MB	75	2	0/2	.75	53.0	8.7
JAL	95	1	1/0	.74	48.0	9.3
JK	99	1	1/0	.77	71.0	13.0
OKH	95	1	1/0	.58	-	8.5

* Days 1-10 only.

sudsing tendency that Neutrogena did. It was concluded that the characteristics of the Neutrogena itself were the principal cause, abetted by the mixing with air and water which occurred during travel through the pickup hose and LGS.

In summary, eleven days of testing on the shower were successfully accomplished. Performance levels were very satisfactory and were very close to anticipated levels based on previous technology contracts.

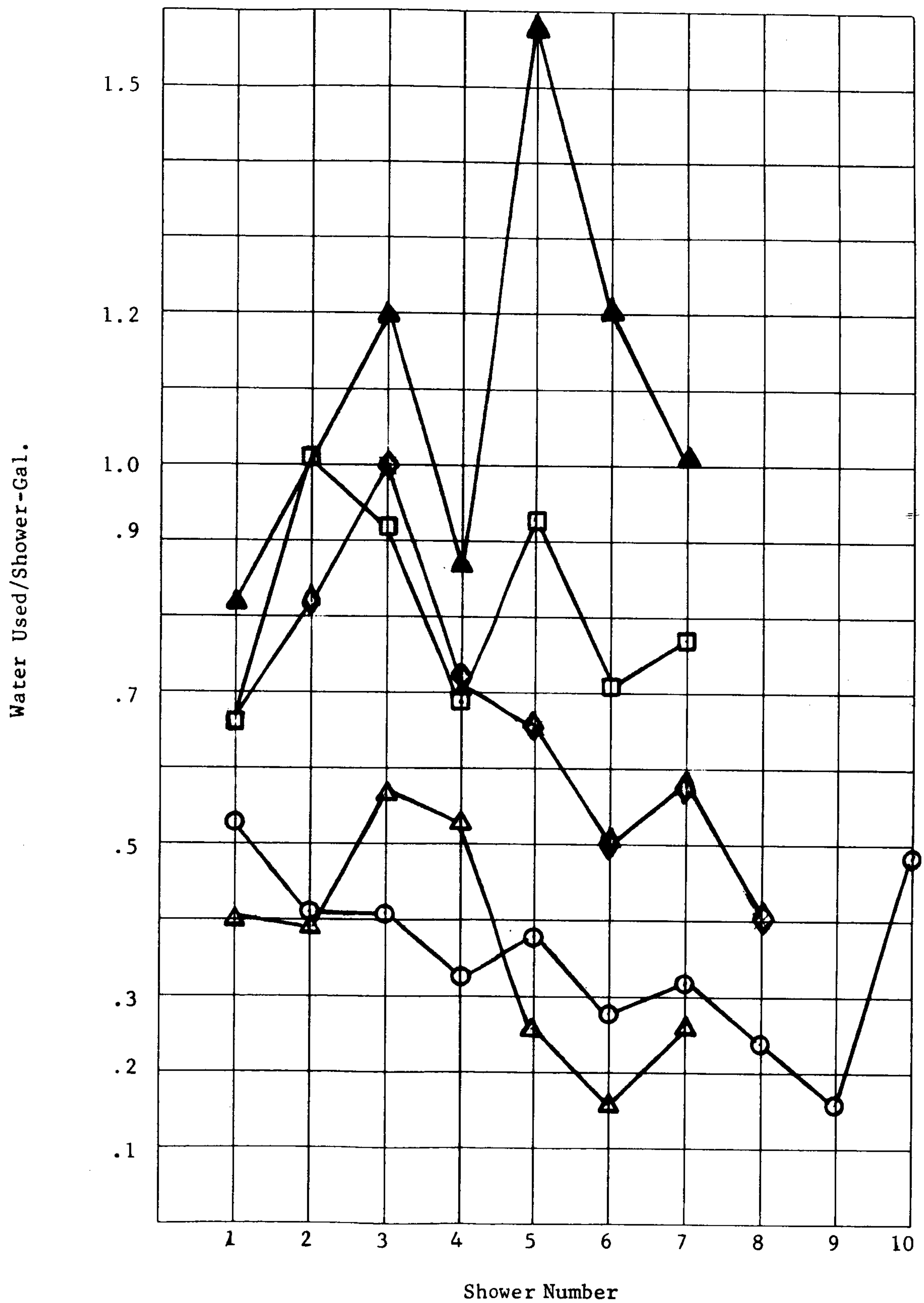


Figure 30 Water Used/Shower-By Subject

4.2.2.2 Noise Levels

Several noise surveys were taken of the shower assembly to determine acoustic levels both outside the assembly and within the shower stall. An initial survey taken of the Hamilton Standard SSP Blower, 89900000851-009 Assy, revealed levels that were extremely high. Figure 31 shows the sound pressure level vs. frequency curves for the various configurations. The curves designated NC-50 and NC-75 are the noise criteria specification for the exterior of the shower assembly and stall interior, respectively.

At frequencies above 500 Hz, the SSP blower was well above the specified maximum levels, with an interior reading of 95 dB at 2000 Hz. These levels were sufficient to warrant using ear plugs (subjects and test personnel) during all test operations with the SSP blower. The ten-day demonstration test was performed in this configuration.

The alternate shower assembly, 89900000851-019, using the Rotron SL2EA2 blower was tested in a special one-day demonstration (Day 11, see paragrpah 4.2.2.5). Sound pressure level measurements of this configuration are also shown in Figure 27. The two curves plotted for the interior levels show how the sound level changed when the Rotron blower was mounted firmly both with and without sound isolation material. The isolation material utilized was three thicknesses of 3/8" Armstrong Cork Armaflex (#12 Durometer), which is a closed cell, sheet insulation (foam) with self-extinguishing properties (ASTMD 1692-68) and a density of 5.7 lb/ft^3.

Although this configuration also exceeded the noise criteria curves at isolated points, the performance improvement is very dramatic, especially at frequencies above 250 Hz. The one-day

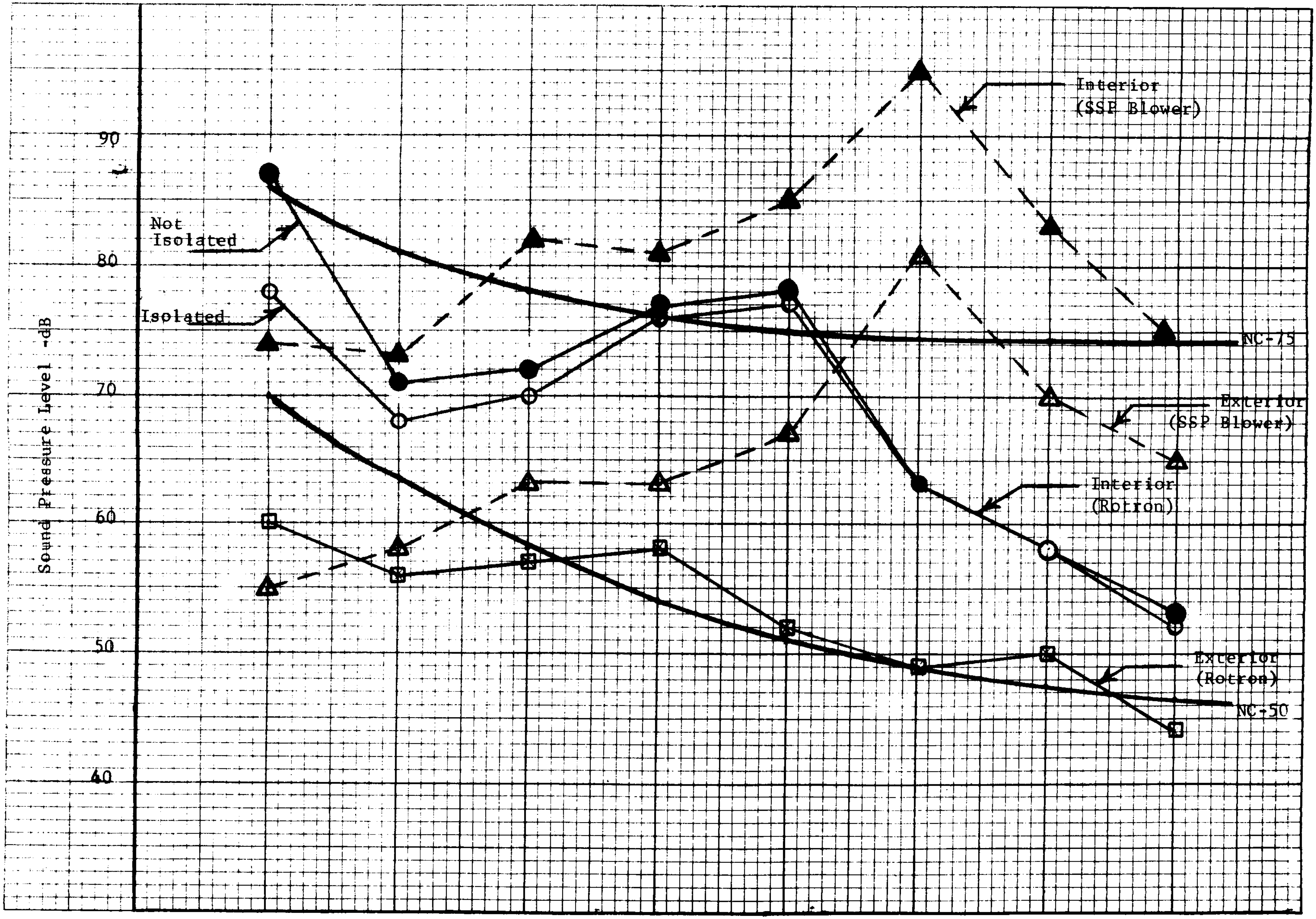


Figure 31 SSP Shower Acoustic Levels.

demonstration test was performed using this blower without any need for ear protection. Some additional sound level reductions might be attainable by using other more sophisticated noise attenuation techniques.

4.2.3 Carbon Dioxide and Relative Humidity Levels

Two additional performance parameters which were monitored during the demonstration tests were carbon dioxide buildup during the showering operation and peak relative humidity levels in the stall. Carbon dioxide readings were taken on Day 5 (during four showers only), Day 6 and Day 7 (during six showers each day) and the relative humidity values were obtained on Days 8 and 9.

Table 14 lists the maximum CO_2 levels recorded for the sixteen showers monitored. It should be noted that the same subject (RP) exceeded the specified level of 3MM level. Since several other subjects of RP's general physical makeup were also monitored (DG and John L) and did not exceed the 3MM Hg level, minor physiological differences are concluded to be the cause of these isolated high readings and the 4.7 scfm bleed air flow which was maintained to control the CO_2 level is considered adequate.

Relative humidity readings were taken by the test subject immediately after rinsing was completed, before cleanup of the stall, using a simple sling psychrometer. In the twelve readings taken the average relative humidity was 88%. Considering the low air flows utilized (33 scfm main, 4.7 scfm bleed), this value is very acceptable.

4.2.4 Microbiological Assay

The shower stall interior surface and air inlet duct to the stall were monitored continually for microbial growth

Table 14 Carbon Dioxide Levels

Subject/Test Day/Shower #	Max. CO_2 Level (MM H_G)	Avg. Max. Level (MM H_G)
John L/Day 5/3	2.28	
DG/Day 5/4	2.47	
MH/Day 5/5	1.54	
TL/Day 5/6	1.34	
DG/Day 6/1	2.54	
John L/Day 6/2	2.35	
TL/Day 6/3	1.87	
RLP/Day 6/4	3.3	2.25
TJ/Day 6/5	1.2	
RC/Day 6/6	1.2	
TL/Day 7/1	2.2	
John L/Day 7/2	2.3	
CC/Day 7/3	2.3	
PG/Day 7/4	2.89	
DB/Day 7/5	2.3	
RLP/Day 7/6	4.0	

during the ten-day demonstration test. The test report gives the procedure utilized to obtain samples for analysis.

Table 15 shows the total microbial count per square foot of sampling area at the various sampling times.

Table 15 Microbial Count

Sampling Area	Bacteria/Sq. Ft. at Sampling Times* 1	2	3	4	5	6
Stall Center	0	2.10^4	108	700	1200	4×10^4
Duct	10	147	144	0	11	36

*1 After cleaning - before test

2 After five days of showers

3 Before cleaning after 48 hours shutdown

4 After cleaning before start of sixth day showers**

5 After 24 hours shutdown - before start of tenth day shower

6 After end of tenth day of showers

** Three showers had been taken before the cleaning process was performed.

The bacteria isolated on the selective media for isolation and identification of human pathogens (BAP and MAP) were not identified as pathogenic. There were some Staphylococcus sp isolated, but these were coagulase negative. (The production of the enzyme coagulase which clots plasma is accepted as a marker of pathogenic strains.) The Gram negative organisms isolated were mostly non-pat ogenic coliforms. At those sample times when there was zero bacteria isolated on TSA, there was also none seen on the BAP and MAP.

The microbial burden of six showers with six different personnel in approximately ninety minutes is consistent with expected levels and does not in itself present any problem. This conclusion is reinforced by the data which showed that there was an approximate 99% reduction in the number of bacteria recovered from the shower body after the shower had been shutdown for a period of 48 hours and an approximate 90% reduction after a shutdown of 24 hours. This indicates an effective way of reducing the microbial burden in the shower. Pathogenic bacteria are quite susceptible to dessication and very few survive after exposure to air for only a few hours. Those bacteria that do survive are generally aerobic spore formers and these are known to be non-pathogenic, is should be noted that many of those bacteria recovered after the 24 and 48 hour shutdowns had the colonial characteristics of the Bacillus species which is a spore former.

It is also significant to note that the air inlet duct maintained a very low microbial count during the entire test period. Although the moist air evolving from the aerosol produced by the liquid/gas separator has the potential for carrying large numbers of bacteria, the increase in temperature of the air as it passes through the heater appears to be quite effective in reducing the number of bacteria.

The bacteriocide (vancide BN in solution) used in cleaning appears to be effective in reducing the microbial count; however, due to the seemingly effective die off during shutdown and the toxic nature of the bacteriocide, it is felt that it could be eliminated from the ZGWBS procedure without causing any problems.

Finally, it is evident from the data that there is no buildup of microbial burden during the 10 day period of the test. 2×10^4/ sq ft and 4×10^4/sq ft are not significantly different due to the nature of the assay procedure. The die off during shutdown prevents any buildup of microbial burden.

4.2.2.5 One-Day Demonstration Test

As a result of the excess noise generated by the SSP blower (89900000851-009 Assy) and since the liquid level sensing system was not operative during the ten-day test, a separate one-day demonstration test was subsequently conducted using an alternate blower (89900000851-019 Assy) and the revised liquid level sensing system.

The alternate blower used was a standard commercial 60 Hz unit, Rotron Model SL2EA2. Since all other electrical power to the shower assembly is 400 Hz. 3Ø, a separate power source was provided. The Rotron blower is mounted in the same location as the SSP blower normally would be and the same ducting is utilized.

The performance of the Rotron blower was very satisfactory. Noise levels were well below those of the SSP blower (see paragraph 4.2.2.2, Figure 27) and, in general, satisfied the noise criteria curves specified. During the test, flow rates were set at 28 scfm main and 6.8 scfm bleed.

The revised liquid level sensing (LLS) system utilizes a thermistor-type high level probe which senses water by means of the resultant temperature difference. This system performed very satisfactorily during the one-day test. The pump activated properly on every occasion and its shut-off point conincided very closely with the point when the sump was totally empty.

4.3 Summary

The SSP Zero Gravity Whole Body Shower System successfully completed all phases of the required test program and demonstrated through consistent performance that it does provide the proper environment for whole body bathing. Performance levels, based on the quantitative test data, were totally acceptable and qualitative performance of the entire assembly was satisfactory.

5.0 FINAL SYSTEM DISCUSSION

The Zero Gravity Whole Body Shower Assembly as designed, fabricated, tested and delivered by Martin Marietta includes several important features which deserve separate discussion. That discussion is presented in the following paragraphs along with final conclusions based on demonstrated shower performance.

5.1 Maintainability

Throughout the evolution of the shower system design, the maintainability criteria established as SSP design guidelines (see paragraph 3.1.2.9) were followed as closely as possible. All hardware items are designed to require a minimum of maintenance and all subassemblies are designed for easy removal and replacement.

Spare units are supplied as identified in Volume II to this report, Dwg. No. 89900000858, and can be easily installed at the subassembly level. For example, the principal electronic components(i.e., flowmeters/signal conditioners, temperature control unit/thermocouple, temperature sensor and switch assembly) can each be replaced by a spare unit (See Operation and Maintenance Manual, Addendum 3, Dwg. No. 89900000859). The relay, transformer and current sensor assemblies are each mounted on separate brackets which can be individually removed. A failed transformer can thus be removed, replaced by a spare, and re-installed with the transformer bracket into the electrical box. The liquid level sensing system is provided with one spare for the active sensor which activates the water pump and one spare for the two sensors used for fault detection (ACE) purposes. A failed sensor can be replaced simply by unscrewing the sensor body from the liquid/gas separator sump, disengaging the electrical connector at the panel, and installing the new sensor assembly (complete with electrical connector).

Those items not specifically spared, such as the liquid/gas separator, air blower, or water pump assemblies, can each be removed for maintenance as required.

Except for the water filter located at the water pump inlet, which requires periodic cleaning, no shower hardware items require scheduled maintenance. Provisions for maintenance in a flight manner are included in the entire shower system.

5.2 Alternate Blower Configuration

The basic shower system is provided with two possible blower configurations. The 89900000851-009 assembly includes the 400 Hz SSP blower, which is identical to other blowers intended for use in the SSP system. The SSP blower performed to acceptable levels in providing adequate pickup through the vacuum system. However, as noted in paragraph 4.2.2.2, the SSP blower far exceeds the noise levels specified and necessitated the use of ear plugs throughout the test period.

As a result, an alternate blower configuration is provided. The 89900000851-019 assembly uses a standard commercial 60 Hz blower which requires a power source separate from all other shower systems which operate on 400 Hz power. The -019 assembly blower performed very well and provided a much improved pickup capability through the vacuum system. In addition, noise levels were markedly lower and, except at isolated frequencies, are below the noise criteria curves specified for the shower (see Figure 27). The improved performance and decreased noise levels of this assembly are of sufficient magnitude to outweigh the complexity factor of introducing the 60 Hz, non-common, unit.

Both blower configurations utilize the same ducting in the air handling system and both operate in the same range of air flows (27-32 scfm main air, 4.7-6.8 scfm bleed air). The higher static pressure of the -019 60 Hz blower accounts for its improved vacuum pickup performance.

5.3 Liquid Level Sensor System

The water level in the liquid/gas separator sump is monitored by a sensing device which, through a control circuit, activates the water pump to remove the shower waste water to the SSP reclamation system. Originally, high and low conductive sensing probes worked in conjunction with each other to activate and turn off the pump at the proper time. Early subassembly checks indicated that these sensors detected the presence of suds in the sump and activated the pump prematurely. This high degree of sensitivity and the assured presence of some suds during normal showering operations led to consideration of other techniques for level control in the LGS sump.

The system chosen for the final configuration was a single high probe of the thermistor type used in conjunction with a commercial power supply and a timing circuit. When the probe is covered by water, the sensor circuitry turns the water pump on for a specified period ($\approx$ 12 seconds). As long as the probe is covered by water, meaning the sump is full, the pump remains on. When water flow into the separator stops and the pump begins to empty the sump, the probe uncovers and the pump shuts off approximately twelve seconds later. The timing is such that the sump can be totally cleared of water in those twelve seconds. Two other sensors, a high and a low probe of the original conductive type, are also located in the LGS sump. These probes do not control the water pump but provide signals to the SSP automatic fault detection system for fault identification and isolation purposes.

This sensing system operated very satisfactorily during performance tests of the entire shower assembly and was able to differentiate between suds and water, thus controlling the water level in the LGS very precisely.

5.4 Conclusions

The following conclusions are presented as a result of the performance of this contract:

1. The zero-gravity whole body shower has demonstrated the ability to provide a safe, comfortable environment in which a crewman can cleanse his entire body.
2. The water, power and time required to perform the showering operations are well within the established criteria and substantiate earlier research.
3. Personal comfort parameters can be adequately controlled to insure that the showering environment achieves crew acceptance.
4. The shower assembly as delivered provides the means to gather further data in the areas of habitability, maintenance, instrumentation requirements and microbiological detection and decontamination techniques, all over extended periods of time.
5. Integration of the whole body shower into a complete Space Station Prototype (SSP) system can be achieved as a further basis for test.

The following recommendations are presented to facilitate future design of a flight article:

1. Structure should be designed for flight loads rather than

shipping restrictions (can be made more aesthetically pleasing).

2. One-piece construction, if possible, to eliminate flange/ gasket in stall.
3. Provide system-compatible blower (materials, electrical interface) with the performance characteristics of the Rotron unit.
4. Provide door with positive latch; eliminate clear plastic.
5. Use liquid/gas separator material which is structurally more durable.
6. Design stall light in order that it can be serviced from the outside.
7. Use larger stall door if shower placement in vehicle allows.
8. Review vacuum pickup hose placement in stall.
9. Re-evaluate need for or scope of fault detection system.
10. Design to make use of or eliminate space saved by absence of soap storage, more limited fault detection system and revised hot water interface.

APPENDIX A

VACUUM PICKUP AND AIR DRAG SYSTEM EQUIVALENT WEIGHT CALCULATIONS

1.0 Vacuum Pickup System

The vacuum pickup system consists of a 45 cfm blower which provides 30 cfm through the shower stall, 10 cfm bleed into the cabin to control the CO_2 level, and 5 cfm for air injection into the liquid-gas separator (LGS) and six towels for drying the crewmen. Shower operation time is scheduled for 15 minutes per crewman. 5.5 minutes to bathe and 9.5 minutes to clean the shower stall and dry his body.

Blower power consumption has an SSP equivalent weight of 62.5 lbs which is derived from the equation watts x power penalty, where Watts $= \frac{.117\ QP}{\mu}$ where .117 is a constant; Q = mass flow, 45 cfm; P = static pressure, 10 inches; μ = efficiency, 60%; and the power penalty is 710 lbs/kw.

$$\text{Watts} = \frac{.117\ (45)\ (10)}{.60} = 88 \text{ watts}$$

Penalty Weight = Watts x 710 lb/kw = 88 x .710 = 62.5 lbs

Air heaters power consumption has an SSP equivalent weight of 73.8 lbs which is derived from the following calculations:

Air Mass = 30 cfm = 137 lbs/hr

Air enters blower - 84.5°F DB/66.5°F WB

Blower adds 5°F - Blower exit air temperature - 89.5°F DB/66.5°F WB

Enthalpy (h) of 89.5°F = 31.1 Btu/lb

Air must be heated to 100°F DB with h of 33.7 Btu/lb

$\Delta h = 33.7 - 31.1 = 2.6$ Btu/lb

Total = Δh x mass flow = 2.6 Btu/lb x 137 lb/hr = 356 Btu/hr

Power = Btu/hr x conversion factor

Power = 356 Btu/hr x .2931 W/Btu/hr = 104 watts

Penalty Weight = 104 watts x 710 lb/kw = 73.8 lbs

Cabin heat load from the 10 cfm bleed air at 89.5°F DB/66.5°F

WB is derived from the change in enthalpy as follows:

Air Mass = 10 cfm = 45.6 lb/hr

Total Δh = Δh from 89.5^{O}F to 49^{O}F + Δh from 49^{O}F to 47^{O}F + Δh from 47^{O}F to 70^{O}F (ambient)

Total Δh = (31.1 - 19.5) + (19.5 - 18.8) + (24.5 - 18.8)

Total Δh = 18.0 Btu/lb, Δh x mass = 82.0 Btu/hr Wt Penalty = 60.6 lbs.

Water Pump power consumption is 57.5 watts for a weight penalty of 57.5 watts x .710 lb/w = <u>40.8 lbs.</u>

Cabin heat load from the opening of the shower door with internal temperature of 87^{O}F with .0199 lb H_2O/lb dry air and the ambient cabin temperature of 70^{O}F DB/57^{O}F WB is derived from the change in enthalpy as follows:

Air Mass = 41.7 ft^3 x 4/hr x .075 lb/ft^3 = 12.5 lb/hr

Total Δh = Δh from 87^{O}F to 49^{O}F + Δh from 49^{O}F to 47 + Δh from 47^{O}F to 70^{O}F (ambient)

Total Δh = (42.8 - 19.5) + (19.5 - 18.8) + (24.5 - 18.8) = 29.7

Δh x mass = 29.7 x 12.5 = 37.2 Btu/hr

Wt Penalty = <u>27.5 lbs.</u>

Total Heat load from moisture carried out on crewman = heat of vaporization of .264 lb/hr <u>264 Btu/hr</u>

Wt penalty = .074 lbs/BTU/hr x 264 Btu/hr = <u>19.5 lbs.</u>

Requirements to wash and dry the six towels each day places a weight penalty of 1104 pounds on the SSP. This penalty is based on the Hamilton Standard study using the washer/dryer combination concept number eight and includes components, power weight equivalents, and heat power weight equivalents.

The total SSP equivalent weight for the vacuum pickup system is 1388.6 pounds.

The atmosphere latent loads on the SSP were determined from the following calculations and test results.

The moisture content of the air released to the cabin from the vacuum pickup air system was determined from tests conducted on Contract NAS1-9819 and calculations. From the test, the following amount of water per pound of dry air was recorded being introducted to the Rotron Blower:

.0212 lb H_2O/lb dry air
.0194 lb H_2O/lb dry air
<u>.0192</u> lb H_2O/lb dry air

For an average of .0598 $\div$ 3 = .0199 lb H_2O/lb dry air

Cabin ambient air at 70°F DB/57°F WB = .0074 lb H_2O/lb dry air

H_2O/lb dry air = .0199 - .0074 = .0125 lb H_2O/lb dry air

Cabin load per hour from bleed air = lb H_2O/lb dry air x bleed air (10 cfm) = .0125 lb H_2O/db dry air x 45.6 lb/hr = .57 lb H_2O/hr

Cabin load per day from bleed air = lb/hr x 1.5 = .57 x 1.5 = <u>.855 lb H_2O/day</u>

Cabin load per hour from moisture retained on the crewmen is equal to 30 grams/shower.

moisture weight = 30 grams/shower x 4 showers/hour = 120 grams/hr

Cabin load = 120 gr/hr $\div$ 454 g/lb = .264 lb/hr

Cabin load per day from moisture on crewmen = lb/hr x 1.5 = <u>.396 lb/day</u>

Cabin load per hour from opening shower door is the introduction of 12.5 pounds of air containing .0199 lb H_2O/lb dry air.

H_2O weight/hr = .0199 lb H 0/lb dry air x 12.5 lb/hr = .248 lb/hr

Cabin load per day from opening shower door = .248 x 1.5 = <u>.372 lb/day</u>

Total cabin atmosphere latent load is 1.082 lb/hr or <u>1.623 lb/day</u>.

2.0 Air Drag System

The air drag system concept utilizes a high volume, 400 cfm, of air to dry the 100 grams of water from the crewman's body and carry the water to the liquid-gas separator. The air blower is sized from NASA CR112006, page 199. The same time line is considered for this system as used for the vacuum pickup system. The air drag system consists of: (1) 470 cfm blower with 6 inches of water static pressure to deliver 400 cfm to the shower stall, 10 cfm to cabin bleed to control CO_2 level, and 60 cfm to the LGS as air injection; (2) regenerative heat exchanger; (3) condenser; and (4) air heater. This is essentially a closed loop system with only the 10 cfm bleed and opening the shower door adding a latent load to the cabin atmosphere. Other parameters are operating temperature 120°F DB and cabin temperature of 70°F DB/ 57°F WB.

Blower power consumption has an SSP equivalent weight penalty which is derived from the equation watts x power penalty where watts = $\frac{.117\ QP}{\mu}$. The .117 is a constant; Q = mass flow, 415 cfm; P = static pressure, 10 inches; μ = efficiency, 60%; and the power penalty is 710 lbs/kw.

$$\text{Watts} = \frac{.117\ (470)\ (6)}{.60} = 549.9 \text{ watts}$$

SSP Penalty weight = watts x 710 lb/kw = 549.9 x .710 lb/w = <u>390.4 lbs</u>

To determine the air heater power penalty, the required temperature rise must be known and several heat loads must be determined first. Since the operating temperature of 120°F DB has been established and there is a 20°F drop going through the shower stall to 100°F DW/72.5°F WB, the heat exchanger, with 85% efficiency, cools the air sensibly to 61.5°F DB/61.5°F WB, reference psychrometric chart.

The condenser will then cool the air temperature down to 49°F DB/49°F WB to get back to the operating line on the psychrometric chart. The condenser load therefore is the difference in the energy required to cool the air which is equal to delta enthalpy times the mass of air as follows:

h for 61°F/61°F = 27.4, h for 49°F/49°F = 19.2

Δh = 27.4 - 19.2 = 8.2 Btu/lb

Air mass = 400 cfm = 1825 lb/hr

Condenser load = 8.2 Btu/lb x 1825 lb/hr = 14,965 Btu/hr

SSP heat power penalty = 14,965 Btu/hr x .054 lb/Vtu/hr = <u>808 lbs</u>.

To the 49°F/49°F air coming from the condenser, the heat added by the blower must be added. The added blower heat is as follows: Q = m Cp ΔT where m = 415 cfm, 1893 lb/hr; Q = 485.5 watts = 485.5 ÷ .291 = 1668 Btu/hr; Cp - .24 Btu/lb/°F.

∴ ΔT = Q/Cp M = 1668 Btu/hr ÷ [.24 Cp x 1893 lb/hr] =3.9°F.

Therefore, temperature out of the blower = 49°F + 4°F = 52°F DB/50°F WB = 20.0 Btu/lb.

Also, the heat exchanger must replace the energy that is removed, which is the difference between the temperature enthalpy: h for 100°F DB/72.5°F WB = 36.8 Btu/lb; h for 61.5°F/61.5°F = 27.4 Btu/lb.

Δh = 36.8 - 27.4 = 9.4 Btu/lb x .85 (efficiency) = 8 Btu/lb

The temperature out of the blower plus the heat added by the heat exchanger gives the cabin bleed temperature. Therefore, the cabin bleed temperature is as follows:

Bleed temp = Blower temperature 52°F (20 Btu/lb + heat from exchanger, 8 Btu/lb = 20 + 8 = 28 Btu/lb from the psychrometric chart raising the temperature sensibly to 84.5°F DB/62.5°F WB.

The cabin heat load from the bleed air is as follows:

h for 84.5°F = 28.2 Btu/lb; h for 49°F = 19.8 Btu/lb

H for 47°F = 18.7, H for 70°F = 24.6

ΔH = (28.2 - 19.8) + (19.8 - 18.7) + (24.6 - 18.7)

Air mass = 10 cfm = 45.6 lb/hr ΔH = 15.4 Btu/lb

Bleed load = 15.4 Btu/lb x 45.6 lb/hr = 702 Btu/hr

SSP heat power penalty = 702 lb/hr x .074 lb/Btu/hr =

52.0 lbs

The air heater power penalty results from heating the air from 84.5°F DB/62.5°F WB sensibly to 120°F DB/72°F WB, which is an enthalpy of 36.8 Btu/lb, to provide the drying air. Therefore, the change in enthalpy is:

36.8 Btu/lb - 28 Btu/lb = 8.8 Btu/lb

Total energy = 8.8 Btu/lb x 1825 lb/hr = 16,060 Btu/hr

Converting energy to power = 16,060 Btu/hr x .2931 watts/Btu/hr

Power = 4705.6 watts

SSP power weight penalty = 4705.6 watts x 710 lb/kw = 3341 lbs

The cabin heat load from opening the shower door is determined from taking the average temperature in the shower stall being cooled from 120°F DB/72°F WB to 115°F DB/71°F WB.

Total ΔH = change from 115°F DB/71°F WB to 49/49 to 47/47 to 70/57

ΔH = (34.5 - 19.8) + (19.8 - 18.7) + (24.6 - 18.7) = 21.7 Btu/lb

ΔH x mass = 21.7 x 12.5 lb/hr = 271 Btu/hr

Wt. penalty = 271 Btu/hr x .074 lbs/btu/hr = 20.0 lbs.

Total heat load from moisture carried out by crewmen:

30GM/shower x 4 showers/hr = 120FMs/hr = .264 lb/hr

In the air drag system, some of this moisture is accounted for in the condenser loads, but as a worst case analysis → heat of vaporization of .264 lb/hr = 264 Btu/hr & wt. penalty = 19.5 lbs.

Water and condenser pumps power consumption penalty is determined by calculating the equivalent weight for the power used. The water pump takes 57.5 watts and the condenser pump is assumed the same 57.5 watts for a total of 115 watts for an SSP weight penalty of:

SSP Weight Penalty = 115 watts x .710 lb/w = 81.6 lbs

The total SSP equivalent weight penalty for the air drag system is 4643 pounds.

APPENDIX B

BULK LIQUID SOAP EVALUATION

MIRANOL® HEATING TEST #1

Purpose: The purpose of this test is to determine a suitable technique for raising the temperature of Miranol C2M-Conc. and Miranol C2M-SF Conc. to an adequate pasteurization temperature using commercially available strip heaters.

Scope: Miranol amphoteric surface active agents have been identified for use as cleansing agents for the Space Station Prototype at NASA-MSC, Houston, Texas. The dispensing container for the cleansing agent used in the zero-gravity whole body shower (ZGWBS) will be heated to an adequate temperature to eliminate most disease carrying cells. The minimum pasteurization requirements are 145°F for 30 minutes and would destroy regenerated cells, weaker spares and most disease producing organisms.

This test will include experimentation implemented to achieve these pasteurization requirements using strip heaters, open aluminum containers insulation and a thermostatic control device.

Test Equipment: The equipment required to perform these tests included the following hardware:

a. 2 - 2 in diameter aluminum containers

b. 1 - 24 watt strip heater

c. 1 - 60 watt strip heater

d. 1 - Thermal couple - thermostat

e. 1 - 1-7/8 in diameter metal container

f. 1 - Thermometer

g. Sufficient supply of Miranol C2M and Miranol C2M-SF

h. Power source of 110 volts

i. Sufficient Armstrong Armoflex Insulation

Test Plan: The test plan will outline various concepts to raise the temperature of the soap within the container and record the time associated with reaching these temperatures. The observer will also record any physical changes in the Miranol experienced while the temperature is being raised. This test will be conducted using each strip heater without insulation, each strip heater with insulation, and the smaller heating unit with an air gap insulation between the heater and the soap.

The Miranol recommended for SSP use exists in two forms. Miranol C2M-Conc and Miranol C2M-SF Conc. Both are chemically identical except that C2M-SF is completely salt free, Miranol C2M-SF Conc is not as viscous as Miranol C2M-Conc which should be an important consideration for storage and dispensing.

Test Procedure: The following test procedure was followed:

1. Measure 4 ounces (approx. 100 grams) of Miranol into the aluminum container.

2. Record initial temperature of Miranol .

3. Activate heater.

4. Record temperature of Miranol in the center of the volume one minute after heaters are activated and 1/2 to 1 minute intervals there after until maximum temperature is achieved.

5. Repeat steps 1 through 4 for the different heaters, insulation, configurations and types of soap described in the preceeding test plan.

Test Results: The results of each test with the larger heater unit showed rapid heating, a high maximum temperature and the following general results.

1. The Miranol that was near the walls of the container came in direct contact with the aluminum container which had the strip heaters attached. The thermal conductivity of Miranol seems less than that of water. The temperature at the center of the container remained relatively unchanged as the temperature near the walls increased.
2. An odor was given off shortly after the temperature began to rise. The temperature at which this occured was when the center portion of the Miranol raised 1°F. in two minutes. The wall temperature was much higher but this wall temperature was not recorded.
3. Bubbles started to appear at the walls when the center temperature was increased to 84°F.
4. A film appeared on the surface of the liquid when the center temperature was increased to 90°F.
5. An increase in bubble activity along the sides occurred when the center temperature was increased to 110°F.
6. Violent foaming occurred 8.5 minutes after the start of the test. The center temperature was at 172°F.

7. The foam started to collect 10.5 minutes after the test was initiated. The center temperature was at 198°F. The test was discontinued because foam began to buildup and would eventually overflow.

8. When the Miranol was cooled to room temperature the collected bubbles form a thick crust on the surface.

This test was performed with both Miranol C2M-Conc and Miranol C2M-SF Conc. The results from both tests were similar except that the violent bubbling occurred in the less viscus C2M-SF approximately one minute earlier than that of the Miranol C2M.

The results of each test with the smaller heater unit showed slower heating capabilities, a lower maximum temperature and the following general results:

1. An odor was given off when the center tempeature was increased to approximately 100°F.

2. The maximum temperature that the center of the Miranol C2M reach was 114°F after 15 minutes of heating.

3. No film collected on the surface of the Miranol.

4. No bubbling occurred at the walls of the container.

The tests were repeated after insulation was secured around the outside of the aluminum container to decrease the heat loss.

1. An odor was given off when the center temperature of the liquid reached 82°F. This occurred 7 minutes after the test was initiated.

2. A film of solids began to collect on the surface of the Miranol.

3. Bubbles began to form along the sides of the container when the center temperature reached approximately 150°F.

4. The bubbles collected on the surface of the Miranol when the center temperature reached approximately 180°F. This occurred 29 minutes after the test was initiated.

5. The surface film collected and the bubbles formed a hard crust, when the Miranol returned to room temperature of 78°F.

6. The maximum temperature which was reached at the center of the liquid was 188°F, thirty-six minutes after the test was initiated. A wall temperature at this time was recorded at 204°F.

To simulate a container concept (tank/internal bellows) a second Miranol container was placed within the aluminum heating unit. An air gap of approximately 1/16 of an inch existed between these two containers to form a layer of insulation. The smaller heating unit was used to achieve a slow temperature buildup and this heater was insulated to get an efficient thermal capacity. The top of the container was capped with a layer of insulation which only allowed a temperature probe to the center of the liquid. No physical changes to the Miranol liquid were recorded during this test.

1. This heating process was the slowest of all previous tests.

2. After 43 minutes the temperature at the center of the liquid reached 152°F. At this point the liquid was checked for bubble activity and it was at a minimum.

3. The maximum temperature at the center of the liquid was reached 53 minutes after the test was initiated and recorded at 207°F.

4. Over a period of 105 minutes the temperature at the center of the liquid leveled off at 206°F and and appreciable amount of bubbles foamed out of the container.

The final test was conducted with the previous set up with the addition of a simple thermocouple temperature control unit placed in series with the heating element. The purpose of this test was to attempt to control the temperature within the range of 165° ± 5°F over a long period of time to achieve the pasteurization conditions.

1. The temperature of the center of the Miranol C2M was increased to 160°F after 25 minutes and was regulated to stay within the desired range of 160°F to 170°F.

2. During this period no bubbles occurred from the sides of the container.

Conclusions and Recommendations: From this series of tests it can be concluded that the temperature of both Miranol C2M-Conc and Miranol C2M-SF Conc can be raised and maintained to an adequate pasteurization temperature using commercially available strip heaters.

From these tests it is recommended that a slow, indirect, heating process be utilized to achieve the desired temperatures. The final test showed that with an air gap between the heated outside wall and the Miranol container the liquid did not bubble at temperature between 168°F and 170°F.

The time period for both the direct and indirect heating process to reach the required temperature varied proportionally. The liquid in direct contact with the heated container reached the required temperature of approximately 165°F within 24 minutes and the liquid with indirect contact required 36 minutes to achieve a temperature of 165°F.

It should also be noted that within the warmup times for each type of heating bubbles collected at the wall surface and started to form a bubble layer at the surface when direct heating was utilized. The indirect process did not have any boiling, bubbles or foam associated when the Miranol liquid reached the required temperature.

From these results it is recommended that a low wattage heater such as the 24 watt strip heater, with proper outside insulation be regulated to achieve the required temperature of 160°F over a longer period of time. It is also recommended that this heater and consequently the wall surface it is adhered to should not come in direct contact with the liquid. If possible a boundry layer of any type of insulation (like air) should be used to distribute the heat equally and more gradually to the liquid Miranol .

MIRANOL HEATING TEST #2

Purpose: The purpose is the same as test #1.

Scope: The scope of test #2 is expanded from test #1 to include a 55 watt probe type heater.

Test Equipment: The equipment required to perform these tests include the following hardware:

a. 1 - 2 in diameter aluminum container

b. 1 - 55 watt, 120 V probe heater

c. 1 - thermometer

d. Sufficient supply of Miranol C2M

e. Power source of 110 volts

Test Plan: The test plan was to heat the soap solution to 160°F with the probe type heater, observe any physical changes, and maintain the solution at that temperature.

Test Procedure:

1. Measure 4 ounces (approximately 100 grams) of Miranol C2M into the aluminum container.
2. Record initial temperatures.
3. Place probe heater in soap solution.
4. Activate the heater.
5. Record the Miranol temperature at the center of the volume at the bottom of the container at periodic intervals.
6. Continue until the maximum temperature (160°F).

Test Results: The soap solution in direct contact with the surface of the heater started to bubble within 30 seconds after the heater was energized. Violent bubbling with an odor followed almost immediately. The heating was continued until noticeable deposits of burned soap were on the heater probe. The heater was then turned off to prevent it from burning out.

Conclusions: The test results showed that this type of probe heater was not suited for the soap heating application. The watt density on the surface area of the heater is 100 watts/in^2, which results in a high heater surface temperature with eventually burned the soap. This ruled the heater out for our application.

MIRANOL HEATING TEST #3

Purpose: To determine the characteristics of Miranol C2M-Conc., Miranol C2M-SF Conc., and a 50/50 solution of water and C2M-SF Conc. during heating to boiling and subsequent cooling to ambient temperatures, and to determine their boiling points at 12.3 psia (ambient at 6000 ft.).

Scope: Since the cleansing agent for use in the SSP must be sterilized, or at least pasteurized, the manner in which Miranol reacts to temperature increases up to the boiling point must be investigated. Surface reactions which might have significant impact on the heating technique must also be known.

Test Equipment: The equipment required for testing included the following:

a. 2-inch diameter aluminum container

b. 24 watt strip heater

c. Thermometer

d. Sufficient supply of Miranol C2M and Miranol C2M-SF

e. Power source of 110 volts

f. Armstrong Armoflex Insulation

Test Plan: Temperatures were taken in the soap on the interior wall surface. Physical changes occurring as the temperature rises were also noted. Heating was continued until boiling of the soap occurred or until physical changes in the soap or soap/water solution made it necessary to terminate the test.

Test Procedure: The test procedure was as follows:

1. Measure 4 ounces (approx. 100 grams) of Miranol or 2 ounces of water and 2 ounces of Miranol into the aluminum container.
2. Activate heater.
3. Record temperature of Miranol (or Miranol /water solution) at the interior wall surface and note the corresponding physical changes in the test solution.
4. Continue heating until boiling occurs or until physical changes in the test solution become large enough to necessitate termination of the test.

Test Results: Boiling was achieved with both Miranol Conc. soaps, but the water/soap solution exhibited a great deal of water evaporation at temperatures between 170 and 190°F. Other test results are listed below.

1. The boiling point of Miranol C2M Conc. is approximately 212°F; of Miranol C2M-SF Conc., it is approximately 193°F.
2. Formation of a surface film occurred in all three tests, with heating and subsequent cooling accelerating the process. This surface film formed most quickly (100°F) in the Miranol C2M-SF and thickened rapidly during subsequent cooling. Film buildup (160°F) and thickening was also present in the Miranol C2M test but was not as pronounced. The effect was present but negligible with the Miranol C2M-SF and water solution.

3. Prior to boiling, all three test solutions exhibited a froth buildup. This froth began to form at 160°F in the Miranol C2M-SF, at 170°F in the Miranol C2M-SF/water solution, and at 180°F in the Miranol C2M.

<u>Conclusions</u>: In general, tests revealed that Miranol C2M and C2M-SF Concentrates, and a Miranol /water solution can be heated to pasteurization temperature (145°F) without adverse effects. Heating above this temperature produces frothing and boiling in the concentrated soaps, and frothing with a large amount of evaporation in the soap/water solution.

MIRANOL C2M-FLOW TEST

Purpose: To determine the flow characteristics of Miranol C2M Conc. during pressurized flow through a 1/4-inch line and to evaluate this technique of dispensing soap to the whole body shower.

Scope: The cleansing agent identified for use in the SSP shower, Miranol , is a liquid concentrate. One method of dispensing the soap for use in the shower would be to pressurize the soap in its storage tank and establish flow through a line system into the shower stall, where a dispensing device could be activated by the crewman. To evaluate such a system, flow rates at various pressures must be known and any tendencies toward clogging in either open or valved lines must be identified.

Test Equipment: The following test equipment was utilized:

1. Storage tank for quantity of Miranol C?M Conc.
2. Pressurant (N_2).
3. Line system of 1/4-inch stainless steel tubing from N_2 cylinder through soap storage tank, additional line from storage tank to two open ends and one check valve release.
4. Supply of Miranol C2M.
5. Scale (flow rate measurement).

Test Plan: Tests were conducted daily for a two-week period with the system left unpressurized between tests. Flow rates out the open ends were measured at various pressures and the performance of the check valve was also evaluated.

Test Procedure:

1. Fill storage tank, if necessary, with Miranol® C2M.
2. Seal system.
3. Pressurize system.
4. Measure flow rate or note flow from open ends.
5. Close open ends and note flow through check valve.
6. Release system pressure.

Test Results: The following results were obtained from the tests:

1. The flow rate out the open end at 5 psig was 2 gm/min, out the check valve at 5 psig was 2.4 gm/min, and at 10 psig out the check valve was 4.3 gm/min.
2. System head (3") in the unpressurized line was sufficient to permit continued seepage out the open ends for some time after pressure was released.
3. Between tests the soap dried at each outlet; this drying did not interfere with flow out the open ends after each 24-hour delay.
4. Flow out the check valve after each 24-hour delay was erratic. In one test dried soap plugged the check valve (designed to open below 10 psig) up to a pressure of 25 psig before permitting flow. Other minimum pressures at

which flow occurred through the check valve were 5 and 8 psig. When the check valve was thoroughly cleaned of soap before pressurization, it opened at 8 psig. When not cleaned, the check valve opened at either 5 or 25 psig; this indicates that the soap either held the valve open or plugged it closed.

5. Soap which seeped from the system between tests made the area appear messy when it dried at the ends of the lines or in the collected pools.

Conclusions:

1. Check valves or other controls may prove unreliable due to plugging. Miranol C2M is a relatively viscous substance which tends to thicken and dry when in contact with air.
2. Seepage and drying at open lines make some sort of valving necessary to avoid loss of soap and inefficient delivery. Daily cleaning of the dispensing device may be required.
3. Low system pressures (10 psig) do not deliver soap at a sufficient rate. Higher pressures, perhaps obtained by a hand-actuated pumping device, are required.

APPENDIX C

BLEED AIR FLOW AND PRESSURE DROP ANALYSIS

. BLEED RATE ANALYSIS

The partially closed air recirculation loop utilized by the ZGWBS allows the CO_2 level in the shower stall to build up during its use to some point above ambient concentrations. To ensure that the maximum level reached during a 15-minute shower is not higher than 3.0 mm Hg (as identified in ZGWBS S.O.W.) for a given bleed flow rate, the CO_2 concentration at a specific CO_2 generation rate, system volume and CO_2 ambient level must be calculated. In order to minimize system weight, the lowest possible bleed rate necessary to maintain proper CO_2 levels must be sought.

Two methods of analysis are possible and they can be used as independent checks on each other. System constants used in both methods are: CO_2 generation rate by the crewman, M_G, is 0.0815 lbm/hr; background CO_2 level, C_B is 2.0 mm Hg; the maximum tolerable CO_2 level in the shower C_S max, is 3.0 mm Hg. The background CO_2 level is that defined in SSP documentation as the nominal ambient CO_2 partial pressure.

The first method of analysis calculates the bleed flow rate required to ensure that the upper limit of the CO_2 concentration, independent of system volume and time, never exceeds 3.0 mmHg. That is, after an unknown period of time, dependent on system volume, the rate at which CO_2 is being exchanged by the bleed flow will be equal to the crewman's CO_2 generation rate. Once this point is reached, no further increase in CO_2 concentration will occur. This can be expressed by the following equation:

$$\Delta CO_2 = CO_2 \text{ generation rate} = \text{outlet } CO_2 \text{ (cfm)} - \text{inlet } CO_2 \text{ (cfm)}$$

$$\Delta CO_2 = .0815 \text{ lbm/hr} \approx .012 \text{ cfm}$$

$$\text{outlet } CO_2 = 3.0 \text{ mm Hg} \times \text{bleed flow rate}$$
$$= .00395\ X$$

$$\text{inlet } CO_2 = 2.0 \text{ mm Hg} \times \text{bleed flow rate}$$
$$= .00263\ X$$

$$\therefore .012 = .00395\ X - .00263\ X$$

$$X = \text{bleed flow rate} = 9.1 \text{ cfm}$$

A more rigorous analysis can be made by applying a differential equation to a control volume containing the shower stall with air flows in and out. This equation is based on a mass balance analysis of the form $\dot{M}_{IN} + \dot{M}_{GEN} - \dot{M}_{OUT} = \dot{M}_{INCREASE}$, where $\dot{M}$ = mass flow (lbs/hr). By inserting system constants and converting to volumetric flow, the mass balance equation becomes a differential equation of the form:

$$\dot{V}C_B + \dot{M}_G - \dot{V}C_S = V_S \frac{dC_S}{dt}$$

, where $\dot{V}$ = bleed flow rate (cfm)

V_S = volume of shower stall (ft^3)

t = time (hr)

C_S = CO_2 concentration (lb/ft^3)

The solution of the differential equation is:

$$C_s = Ae^{-(\dot{V}/V_s)t} + \frac{\dot{V}C_B + M_G}{\dot{V}}$$

The constant A can be determined from the boundary condition that at time $t = 0$, $C_s = C_B$. Therefore,

$$C_s = C_B = Ae^{o} + \frac{\dot{V}C_B + M_G}{\dot{V}}$$

$$\text{or} \quad A = -\frac{M_G}{\dot{V}}$$

The particular solution of the differential equation then becomes:

$$C_s = -\frac{M_G}{\dot{V}} e^{-(\dot{V}/V_s)t} + \frac{\dot{V}C_B + M_G}{\dot{V}}$$

, where $V_s = 40\ ft^3$.

As a check of the first method of analysis, a bleed flow rate ($\dot{V}$) of 9.1 cfm can be substituted into the equation and the CO_2 concentration after 15 minutes (1/4 hr), the maximum period of shower operation for one crewman, can be determined. For the system constants defined earlier, this value of C_s is 3.01 mm Hg, which agrees with the results of the first analysis. This second analysis also shows that the maximum CO_2 level of 3.0 mm Hg will be reached but not surpassed during one shower cycle for a bleed flow rate of 9.1 cfm and a shower volume of 40 ft^3.

The above analyses show that the anticipated bleed flow rate of 10 cfm for the ZGWBS will be sufficient to insure that the CO_2 in the shower will not exceed 3.0 mm Hg during a 15-minutes shower cycle.

TOTAL SYSTEM PRESSURE DROP ANALYSIS

In order to determine the operational characteristics of the blower utilized in the ZGWBS, the total system pressure drop must be determined. This system pressure loss in turn fixes the static pressure and, thus, the volumetric air flow rate at which the blower will operate. The static pressure versus air flow characteristics for the particular blower chosen for use are illustrated in Figure 32 below.

The total system pressure drop can be calculated by considering the pressure loss in each individual component of the system and totaling those losses. The individual components of the ZGWBS which will be considered, starting at the blower outlet, are as follows (see Figure 20):

1) 1-3/4" dia. line, 3" length, T-shape to air heater and LGS air injection line
2) Transition piece, 6" length, 1-3/4" to 2" dia.
3) Flowmeter.
4) Air heater.
5) Elbow, r/d defined as 1.5.
6) Shower stall, inlet and outlet (vacuum line), 30" dia.
7) Vacuum pickup head.
8) Vacuum pickup line, 6' hose, 1-1/4" dia.
9) Transition piece, 5" length, 1-1/4" to 2" dia.
10) Elbow, r/d defined as 1.5.
11) Liquid/gas separator.
12) Transition piece, flexible (elbow) 12" length, 2-1/2" to 1-3/4" dia., to blower inlet.

The pressure losses through each item are calculated in the following steps.

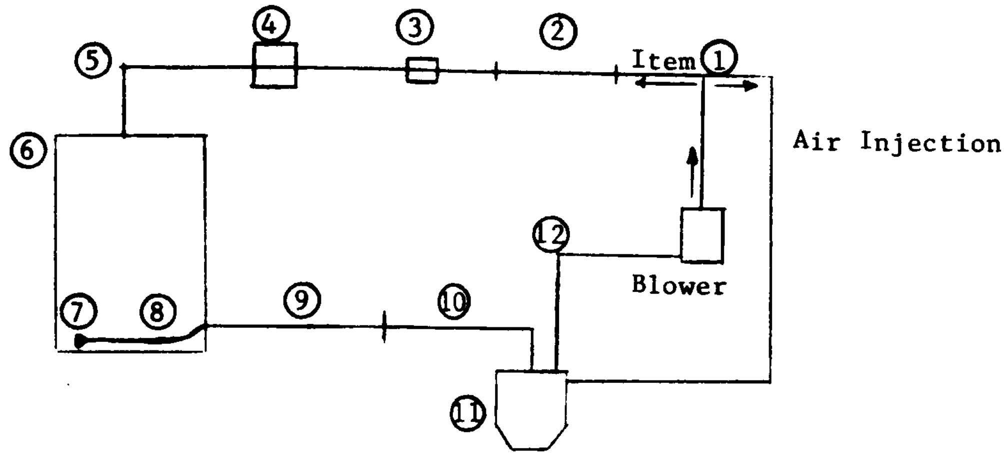


Figure 32 ZGWBS Pressure Loss Model

Item 1

The line is assumed to be Schedule 40S stainless steel pipe; for a nominal diameter of 1-3/4", the inside diameter is 1.84".

The equivalent length of the T-section, for a miter bend of 90^{o} is 58 diameters or 1.84" x 58 = 108"

Air flow through the T to the air heater is

BLOWER OUTLET FLOW (45 CFM ASSUMED) - AIR INJECTION FLOW (5 CFM) = 40 CFM

$$\Delta P = 43.5 \frac{fL\rho q^2}{d^5}, \text{ where } L = \frac{108 + 3}{12} = 9.16 \text{ ft.}$$

$$f = .01$$

$$q = 0.67 \text{ cfs}$$

$$\rho = .0753 \text{ lb/ft}^3$$

$$\Delta P = 43.5 \frac{(.01)(9.16)(.0753)(.45)}{21} = 0.007 \text{ psi}$$

Item 2

As a worst case, the transition piece will be treated as a sudden expansion of flow:

$$\frac{d_1}{d_2} = 0.89 \longrightarrow K = 0.03 \text{ (resistance coefficient)}$$

$$v = 27 \text{ fps (30 cfm, mean dia.)}$$

$$\Delta P = \frac{Kv^2 \rho}{2g\ (144)}$$

$$\Delta P = \frac{.03(27)^2(.0753)}{(288)(32.2)} = .00018 \text{ psi}$$

Item 3

The pressure loss in the flowmeter is defined by specification to be less than 1" H_2O. (Loss assumed = 1" H_2O)

Item 4

The pressure loss through the air heater is assumed to be 0.1" H_2O.

Item 5

For r/d = 1.5, the total equivalent length is 13 diameters or 2.067" x 13 = 26.9".

$$\Delta P = 43.5\ \frac{fL \rho q^2}{d^5}, \text{ where } L = \frac{26.9}{12} = 2.24 \text{ ft., } f = .01,$$

$$q = 0.5 \text{ cfs (30 cfm)}$$

$$\Delta P = 43.5\ \frac{.01(2.24)(.0753)(.25)}{37.7} = .00049 \text{ psi}$$

Item 6

Four factors must be considered in determining the pressure loss through the shower stall: 1) sudden expansion into stall, 2) sudden contraction into vacuum pickup head from stall, 3) resistance due to pipe exit (2" line into stall), and 4) resistance due to pipe entrance (vacuum pickup head).

For sudden expansion:

$$\frac{d_1}{d_2} = \frac{2.067}{30} = .069 \longrightarrow K = 0.98$$

$$\Delta P = \frac{Kv^2}{2g\ (144)}, \text{ where } v = 21.4 \text{ fps (30 cfm in 2" line)}$$

$$= \frac{.98(21.4)^2(.0753)}{(288)(32.2)} = .0036 \text{ psi}$$

For sudden contraction, K = .48 and ΔP = .0018 psi.

The total resistance factor, K, for pipe exit and entrance is 1.0 + 0.04 = 1.04 (sharp-edged exit and well rounded entrance) and the pressure loss is .0038 psi.

In all four subtotals calculated here, the velocity used was that in the 2" line, which is an extreme worst case analysis. The total pressure loss in the shower stall is:

$$\Delta P = .0036 + .0018 + .0038 = .0092 \text{ psi}$$

Item 7

The vacuum pickup head contains a screen to collect gross contaminants and the pressure drop across this screen is assumed to be 0.1" H_2O.

Item 8

The vacuum pickup line has a smooth interior surface, a diameter of 1-1/4" and a length of 6 ft. Therefore,

$$\Delta P = 43.5\ \frac{fL\rho q^2}{d^5}, \text{ where } f = .01 \text{ and } q = 0.5 \text{ cfs (30 cfm)}$$

$$\Delta P = 43.5\ \frac{(.01)6(.0753)(.25)}{3.04} = .016 \text{ psi}$$

As a worst case, the flexible line could contain several bends which would increase resistance along the line. Two 90° bends with r/d defined as 1.5 and one bend with r/d defined as 15 will be assumed. The corresponding equivalent lengths are:

1.25" x 13 x 2 = 39.5" and 1.25 x 41 = 51.3"

Therefore,

$$\Delta P = 43.5 \frac{fL \rho q^2}{d^5} = 43.5 \frac{.01(32.5+51.3)(.0753)(.25)}{(12) \quad 3.04} = .019 \text{ psi}$$

The total pressure loss in the vacuum line is .035 psi.

Item 9

The transition piece is treated as a sudden expansion and

$$\frac{d_1}{d_2} = \frac{1.38}{2.067} = .67 \longrightarrow K = 0.3$$

$$\Delta P = .0021 \text{ psi } (v = 31 \text{ fps})$$

Item 10

As for item 5, r/d = 1.5 and the equivalent length is 26.9". Therefore, ΔP = .00049 psi.

Item 11

The pressure loss in the liquid/gas separator is defined to be 3" H_2O.

Item 12

The flexible transition piece has a maximum friction factor of .03 and a maximum flow of 45 cfm through its 1' length. Therefore,

$$\Delta P = 43.5 \frac{(.03)(1)(.0753)(.67)^2}{10.8}, \text{ where } d = 1.61 \quad d^5 = 10.8$$

$$= .0041 \text{ psi.}$$

Additional losses occur due to sudden contraction and resistance to bending.

$$\frac{d_1}{d_2} = \frac{1.84}{2.47} = .75 \longrightarrow K = .17, \quad v = 26.4 \text{ fps}$$

$$\Delta P = \frac{.17(26.4)^2(.0753)}{288 \ (32.2)} = .00096 \text{ psi}$$

and the ΔP due to bending is .0005 psi (using mean diameter and velocity same as item 5). Thus, the total ΔP for item 12 is .00556 psi.

Pressure losses from items 1, 2, 5, 6, 8, 9, 11 and 12 total 0.06 psi, or 1.66 inches of water. Adding the losses defined for items 3, 4, 7 and 10, the total system pressure drop becomes 5.86" H_2O. At this static pressure, the blower air flow rate is 51 cfm, rather than the initially assumed 45 cfm. Theoretically, the pressure losses should be recalculated at the higher flow rate; however, since the flow rates through the shower stall and the LGS air injection port could remain at 30 and 5 cfm respectively, and the bleed flow rate could be increased from 10 to 16 cfm, the impact of this flow system on the pressure loss total would be very minimal and the blower air flow rate would remain very close to 51 CFM.

APPENDIX D

SSP ZERO GRAVITY WHOLE BODY SHOWER
STRESS ANALYSIS

TABLE OF CONTENTS

1.0 Introduction

This section presents a detailed stress analysis on the SSP zero gravity whole body shower. It's purpose is to illustrate through analysis the structural capacity and determine the load level and modes of failure.

2.0 Summary

MCR 72-154 preliminary design review Appendix C presents the preliminary stress analysis. This was a limited design effort, and will be expanded in this analysis.

3.0 Method of Analysis

The method of analysis used herein will be elastic except as noted. All assumptions associated with the small deformation theory are applicable.

Structural redundants are eliminated by using overlapping assumptions.

4.0 Loads

The loads definitions used in this analysis are listed below:

Design Ultimate Load - A load equal to the design limit load multiplied by the ultimate factor of safety. Failure shall not occur at or below the design ultimate load.

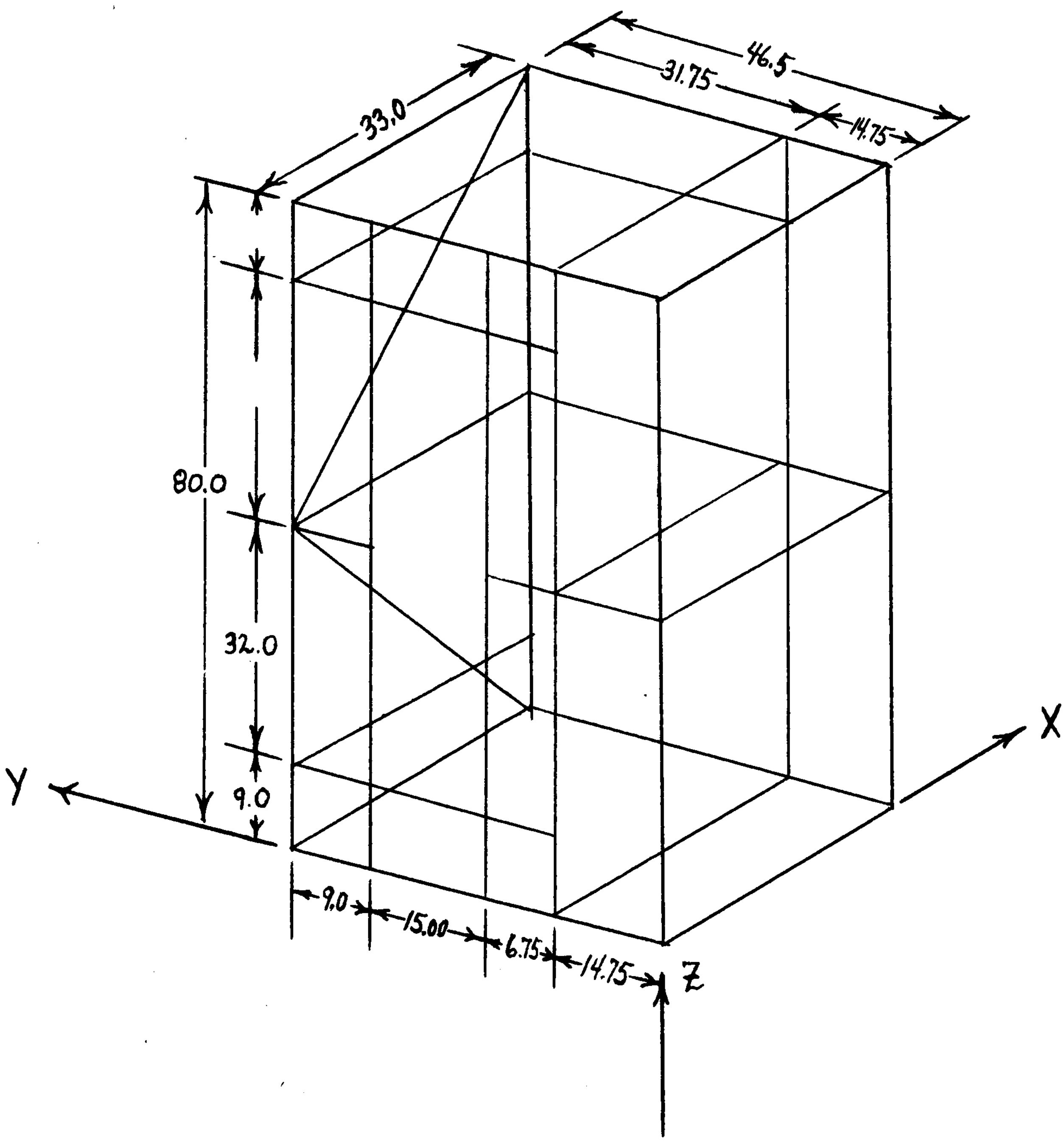
Design Limit Load - A load which established a strength level for design of the shower and its components. It is expected to be 10 G's maximum in any direction for the life of this structure. A factor 1.1 will be used against limit load to get design limit load.

4.1 Ground Loads - Assume a 200 pound load applied in any direction at any location.

4.2 Operating Load - The maximum limit design load shall be 10 x 1.1 = 11 G's in any direction. The maximum ultimate load shall be 10 x 1.5 = 15 G's any direction.

5.0 Geometry

The general structural configuration and positive sign convention shown below will be used through this analysis. See drawing number 89900000851 for detail part configuration.



6.0 Material Allowables

The material selected for fabrication was 6061-T6 aluminum. It was selected because of its good formability, weldability, corrosion resistance and strength after heat treatment.

It is well known that the members when welded reflect a strength reduction in the areas adjacent to the welds area called the heat effective zone.

If the overall structure may be shown adequate for this reduced strength due to welding it can be said the analysis is conservative.

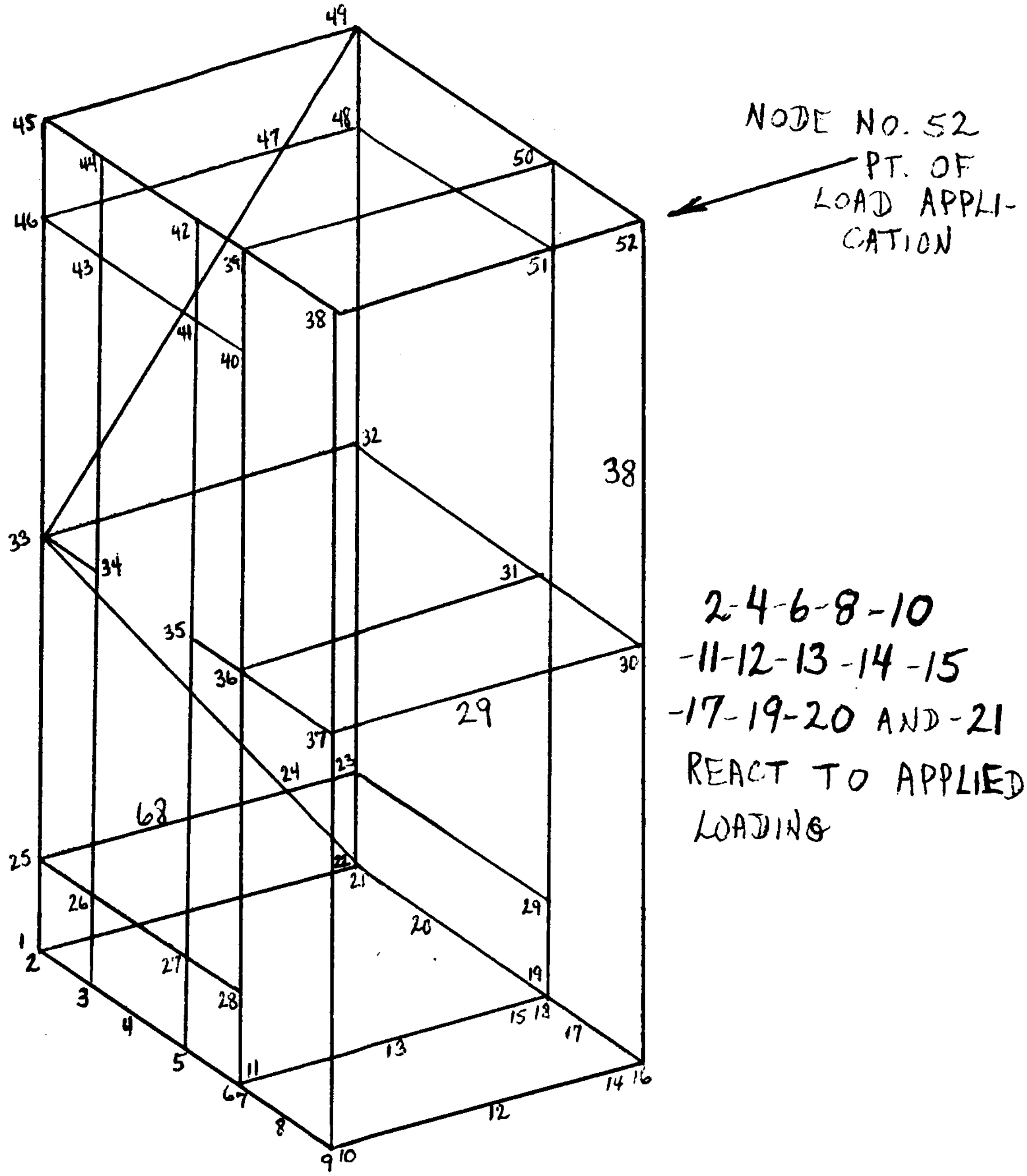
Material Properties 6061-T6 Welded

Properties	E	G	F_{tu}	F_{ty}	F_{tv}	F_{brv}
Min-Value KSI	10×10^3	3.75×10^3	27	17	35	56

Properties shown above per Ref. 5.0. All bolts used in this assembly shall be 5/16 dia. A-286 steel bolts with tension type nuts.

7.0 Stress Analysis

The stress analysis shown herein is based on a direct stiffness solution for a space frame supported at the base and loaded at the top. This idealized structure with node points is shown below.


NODE NO. 52
PT. OF
LOAD APPLI-
CATION
2-4-6-8-10
-11-12-13-14-15
-17-19-20 AND -21
REACT TO APPLIED
LOADING

7.1 Method of Loading Idealized Structure - Since there are no physical members between the structural centroid and the frame structure, a method which would cause the worst effects was imposed; all loads were applied thru node No. 52.

Four load cases were used in an effort to envelope the critical loading seen by the true structure.

The loads applied, their direction and magnitude, are shown below:

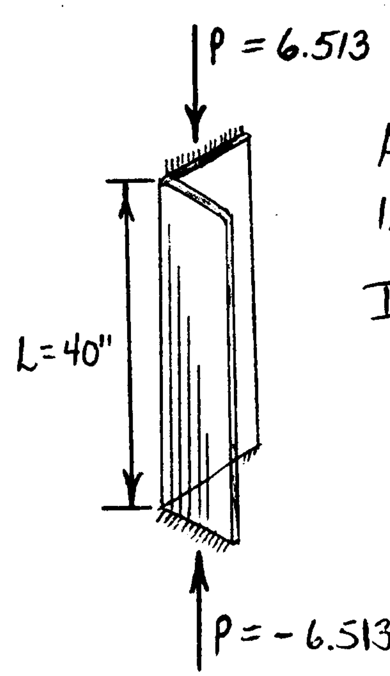
Condition	FX	FY	FZ
1-15G-@45°	-4.78K	+4.78K	0
2-15G-X	+6.74K	0	0
3-15G-Y	0	+6.74	0
4-15G-Z	0	0	+6.74

Estimated Weight 430#

The results of the stiffness analysis are listed in the computer analysis section 8. Shown in this section are typical members and how they were analyzed.

7.2 Typical Column Analysis - For member No. 38 shown on page 7.

Loading Condition 4 - 156



AREA = .290 IN²

1.25 X 1.25 X 1.25

$I_x = I_y = .0420$ IN⁴

$I_{MIN} = .017$

$\rho_{MIN} = .25$ IN

Since both ends are restrained,

$$\sigma_{cr} = \frac{4\pi^2 E}{(L/\rho)^2} = \frac{4 \times 9.85}{\left(\frac{40}{.25}\right)^2} \times 10^4$$

$$\sigma_{cr} = \frac{39.40 \times 10^4}{2.5 \times 10^4} = 15.75 \text{ KSI}$$

True compression stress:

$$\sigma_c = \frac{P}{A} = \frac{6.513}{.290} = 22.5 \text{ KSI}$$

$$\text{M.S.} = \frac{\sigma_{cr}}{\sigma_c} - 1 = -19.5\%$$

This is really -4.5% below the ten "G" level satisfactory for fabrication. Inelastic deformation will pick up this -4.5%.

7.3 Typical Local Buckling Analysis - This section will set the design criteria needed in connection with local behavior of plate elements, of columns and the design of local elements to withstand shear forces developed as a result of eccentricity of load, or lateral loads.

The following equation from Ref. 6 will be used to approximate the critical buckling stress of a flat-plate segment in a long column under uniform compressive stress in either the elastic or inelastic range.

$$\sigma_c = K \frac{\pi^2 E \sqrt{N}}{12(1-\mu^2)(b/t)^2}$$

n = Et/E

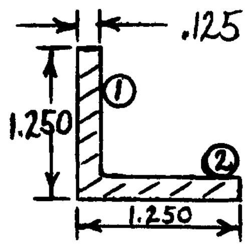
K = Factor based on boundary conditions

For a fixed-fixed column = 6.97

Et $\cong$ E for elastic buckling-in alum.

$$\sigma_c = 6.97 \frac{9.869 \times 10^7}{12(.89)(b/t)^2} = \frac{6.45 \times 10^7}{(b/t)^2}$$

Typical Column Cross Section



$$b/t = \frac{1.250}{.125} = 10.0 \therefore (b/t)^2 = 100$$

$$\sigma_{cr} = \frac{6.45 \times 10^7}{10^2} = 64.500 \text{ PSI} > F_{tu}$$

This indicates local buckling is prevented in the elastic range.

Crippling Stress Total Check

ELEM	b	t	bt	b/t	F_{CC}	F_{CC} bt
1	1.250	.125	.1563	10.0	12.25	1.92
2	1.250	.125	.1563	10.0	12.25	1.92
Σ			.3125			3.84

$$F_{cc} = \frac{\sum F_{ccibt}}{bt} = \frac{3.84}{.3125} = 12.3 \text{ KSI}$$

$$f = \frac{P}{A} = \frac{6.513}{.3125} = 20.8 \text{ KSI}$$

$$\text{M.S.} = \frac{F_{cc}}{f} - 1 = -40.5\%$$

7.4 Summary of Buckling and Local Buckling Analysis - Both sections 7.2 and 7.3 indicated margins against ultimate load; therefore, a larger section will be used.

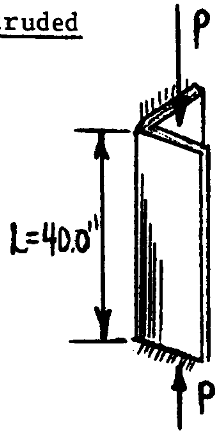
Try a 1.25 x 1.25 x 3/16 extruded

Section Properties

$A = .43\ in^2$

$I_x = I_y = .059\ in^4$

$I_z = .025\ in^4$ (Min)



Fixed-Fixed Col.

$$P_{cr} = \frac{4\pi^2 EI}{L^2} = \frac{4 \times 9.869 \times 10^4 \times .025}{1600}$$

$$P_{cr} = 6.16\ \text{KIPS}$$

$$P_{Applied} = 6.513$$

$$\sigma_{cr} = \frac{P_{cr}}{A} = \frac{6.16}{.43} = 14.5\ \text{KSI}$$

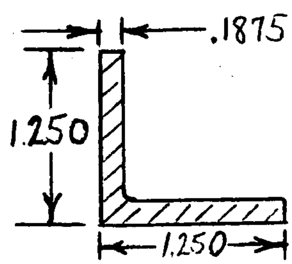
True Stress $\sigma_{+} = \frac{6.513}{.43} = 15.15$ KSI

$$M.S. = \frac{\sigma_{cr}}{\sigma_{+}} - 1 = -4\%$$

-4% M.S. is acceptable since this is at a stress below yield ∴ plastic redistribution will aid this buckling effect.

Typical Revised Cross Section

$\sqrt{\frac{F_{cy}}{E}} = \sqrt{35 \times 10^{-4}} = 5.9 \times 10^{-2} = .059$ Use for non-dim. Crippling Curves



ELEM	b	t	bt	b/t	F_{CC}	F_{CCbt}
1	1.250	.1875	.232	6.67	35	5.85
2	1.250	.1875	.232	6.67	35	5.85
$\sum$			.464			11.70

$$F_{CC} = \frac{\sum F_{ccbt}}{bt} = \frac{11.70}{.464} = \underline{25.4KSI}$$

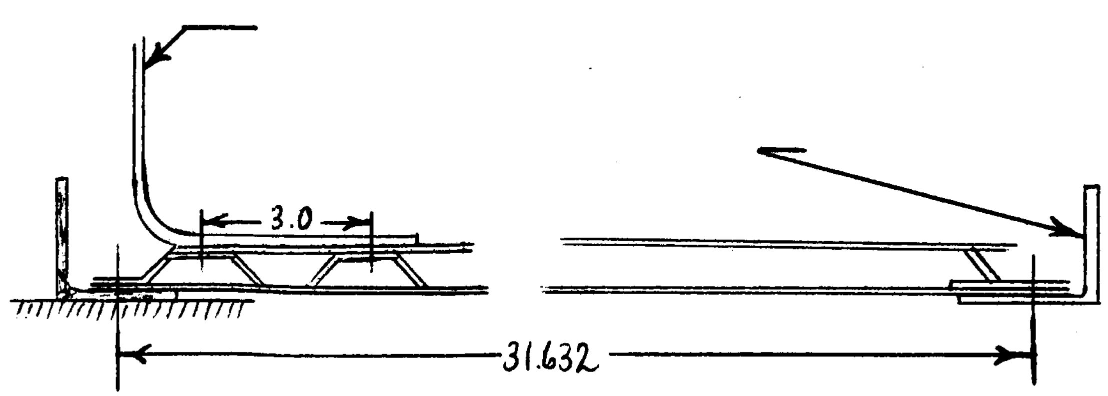
$$\text{Compression stress} = f = \frac{P}{A} = \frac{6.513}{.3125} = 20.8KSI$$

$$M.S. = \frac{F_{cc}}{f} - 1 = \frac{25.4}{20.8} - 1 = +22\%$$

This section will not cripple when subjected to 15G's

7.5 Floor System Design - The floor system for the shower stall is welded .063-6061-T6 aluminum. The floor spans a 30.382x31.632 area. It is felt that excessive deflection would be experienced during use; therefore, the floor system will be stiffened with sheet metal hat-sections.

Typical Cross Section

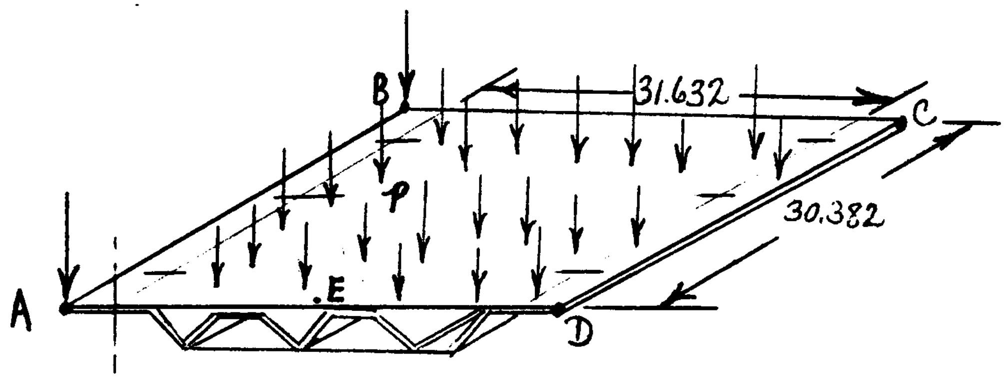


Floor Load - Reference 2-NASA SP-3006 bioastronautics data book-body dimensions of U.S. males page 14.2 for 95 percentile gives foot size of 11.0 x 4.8 or 52.8 in^2 - Total area - 2 x 52.8 = 105.6 in^2

Assume 55% effective contact bearing - Total pressure $= \frac{200\#}{105.6 \times .55} = 3.45$ PSI

By geometry the sub-floor is to be supported on three-sides, while the fourth side is free. If it is designed for a uniform pressure of 3.5 PSI uniformly and a limit deflection of .15, the sub-floor would support a 200# man in any position.

Idealized Structure



Sides "AB" - "BC" and "CD" are simple supported; side "DA" is free

Let b = 31.632 and a = 30.382

The following analysis is per table 42 of Ref. 3 page 212

$b/a = \frac{31.632}{30.382} = 1.042 \longrightarrow$ Use 1.0

7.5 Floor System Design-Cont'd

Plate Analysis-Cont'd

The maximum moment at the center of the free edge point "E"

$$M = \beta p a^2 \quad : \beta = .112; \; p = 3.45 \text{ PSI} \quad a = 30.38$$

$$M = .112 \times 3.45 \times \overline{30.38}^2 = 356 \text{ in. \#/in.}$$

The bending moments at the geometric center are

$$M_x = .08 p a^2 = 255 \text{ in-\#/in}$$

$$M_y = .039 p a^2 = 124 \text{ in-\#/in}$$

The maximum stress in the facing skin is:

$$\sigma = \frac{M}{(D-t)t} \quad : \quad \text{where } t = \text{facing skin}$$

D = Depth of section = .50

Let $\sigma = \sigma_y$ = Fty for 6061-T6 nonwelded = 35 KSI

$$35 = \frac{.356}{.5t-t^2} \quad \text{or} \quad t^2 - .5t + .0102 = 0$$

Expanding and solving the quadratic

$$t = \frac{.5 \pm \sqrt{(1.5)^2 - 4(.0102)}}{2} = .021 \text{ in}$$

7.5 Floor System Design-Cont'd

Checking the required facing thickness at σ equal to the ultimate material allowable and if the subject was standing on one foot:

$$p = \frac{200.0}{52.8 \times 55\%} = 6.9 \text{ PSI}$$

Again the maximum bending moment is at the geometric center of the free edge

$$M = .112 \times 6.9 \times 30.38^2 = 712 \text{ in-\#/in}$$

$$\sigma = \frac{M}{(D-t)t} = F_{tu} = 38 \text{ KSI} \quad \text{nonwelded}$$

$$D = 1/2 = .50 \text{ in.}$$

$$t^2 - .5t + .712/38 = 0$$

$$t^2 - .5t + .0188 = 0$$

$$t = \frac{.5 - \sqrt{.25 - 4(.0188)}}{2} = .042 \text{ in.}$$

For design use t = .050

$$\sigma = \frac{712}{.45 \times .05} = 31.6 \text{ KSI}$$

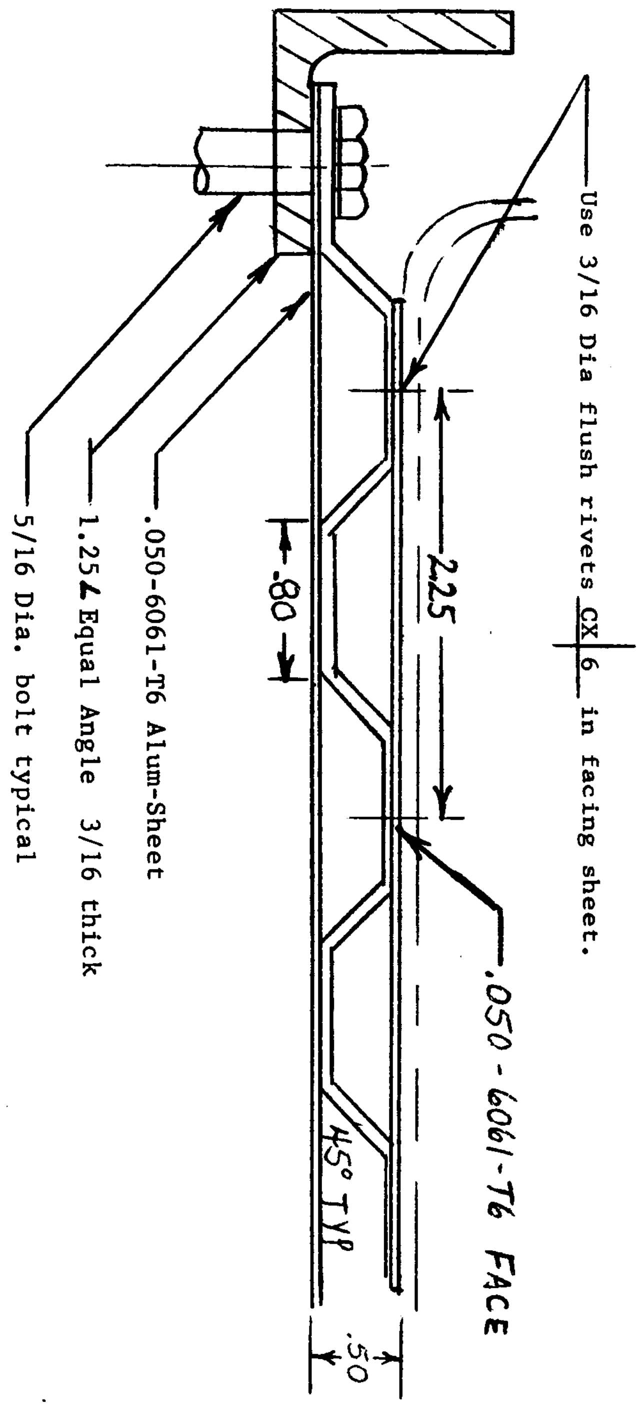
$$\text{M.S.} = \frac{F_{tu}}{G} = 1$$

$$\text{M.S.} = \frac{38}{31.6} - 1 = +20\%$$

See final design next page

7.5 Floor System Design-Cont'd

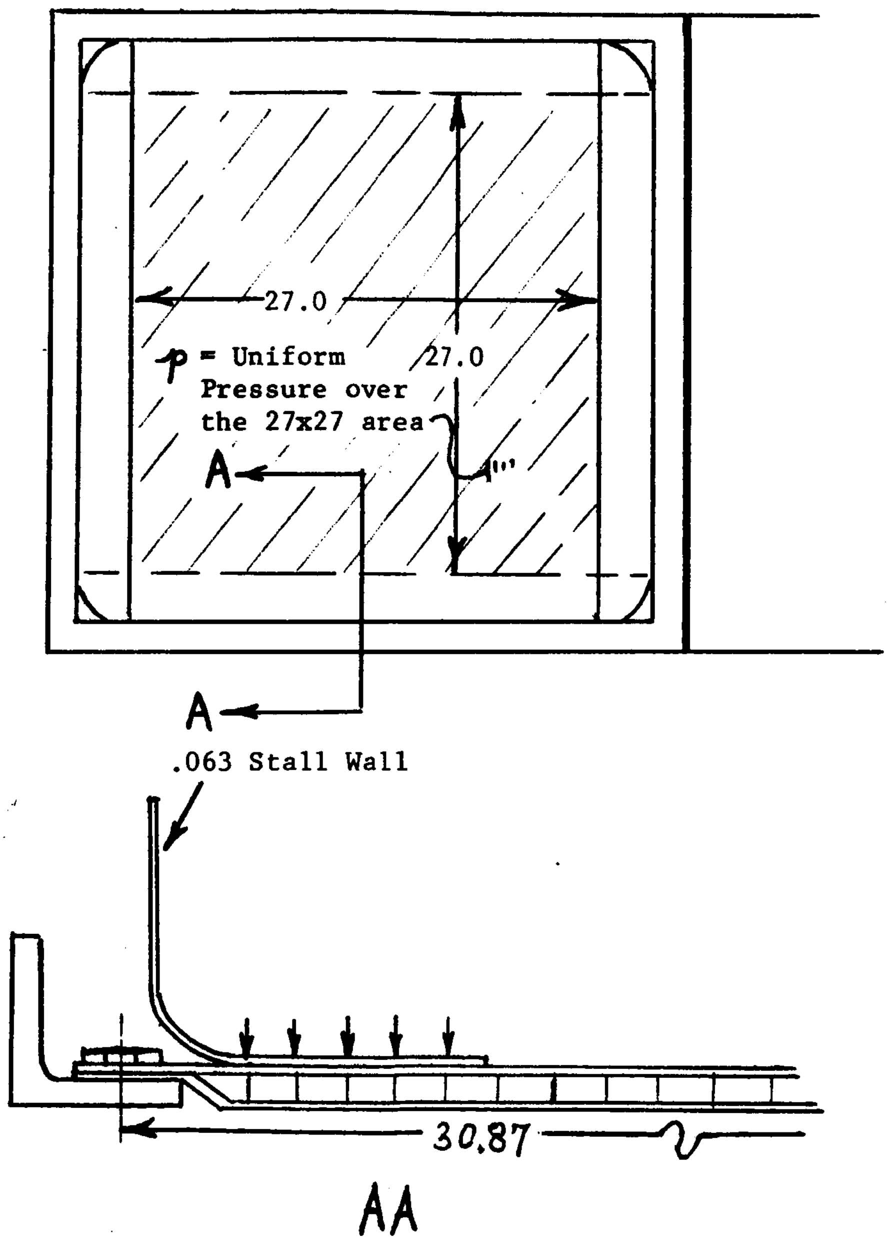
Full Scale Floor



7.6 Shower Stall Floor Design-Cont'd

Ref. Dwg. 89900000871-LWR shower stall assy. This is a welded up .063-6061-T6 Aluminum structure. It is required to support a 200# man.

Geometry and Loading:



Determine "p"

Reference 2, NASA-SP-3006 "Bioastronautic Data Book"

Body dimensions of U.S. males page 14.2

Percentile- 95th

Foot size = 11.0 x 4.8 = 52.8 in^2

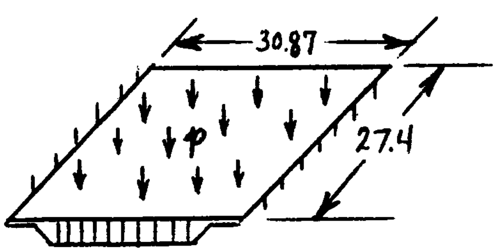
Total area = 2 . 52.8 = 105.6 in^2

Total man's weight 1G = 200#

$$p = \frac{200}{105.6} = \underline{1.9 \text{ PSI}}$$

Panel Design

If the floor panel is designed for a uniform pressure of 1.5 PSI and .150 in. maximum deflection it can support the 200# man at any location on the panel.



The structure shown at the left is an idealization of the true structure. It is supported on two sides, loaded by a uniform pressure of 1.5 PSI ultimate.

Plate analysis per Timoshenko's plates and shells page 218 art 49.

Floor Panel Design

Let b = 30.89 and a = 27.4

b/a = 30.89/27.4 = 1.12 Use 1.0.

Ref. Table 47 - of Ref. 3

The maximum bending moment is:

$M_x = \beta pa^2$ At a/2 : b/2

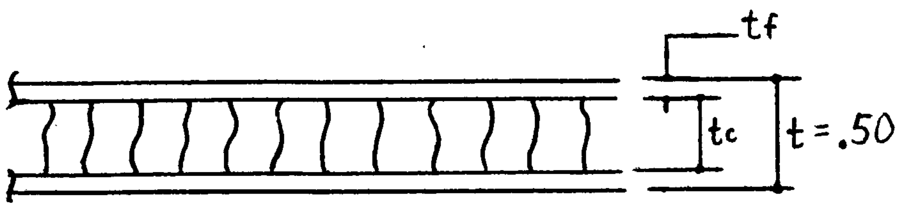
β = .1318

M_x = .1318 x 1.5 x (27.4) = 148 in#/in

Per Ref. 4 the facing stress is:

$\sigma_f = \frac{M}{tctf}$ Based on geometry below.

tc = t-2tf



Limit the stress to 95% FTU for 6061-T6

90% F_{tu} = .90 x 42 = 38 KSI

$\sigma_y = 38.000 = \frac{.148}{tf(t - 2tf)}$

Expanding and solving for tf

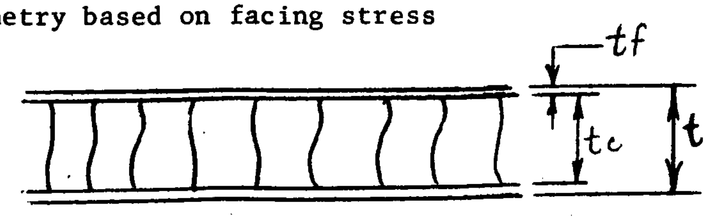
$tf^2 - .25tf + .00195$

$tf = \frac{.25 \pm \sqrt{(.25)^2 - 4(.00195)}}{2}$

tf = .008 Use tf = .012 min. gage

Floor Panel Design

Geometry based on facing stress



t = .50
tc = .476
tf = .012

Max. deflection is:

$\delta = \frac{\alpha_2 P a^4}{D}$ Ref. 3 Table 47

α_2 = .01509

$$D = \frac{E_f \, t_f \, t_c \, t}{2\lambda_f} \qquad \text{Ref. 4}$$

Where

E_f = modulus of elasticity of facing

$n = 1-(\mu)^2 = .89$ for 6060-T6

$$D = \frac{10^7 \text{ PSI} \times .012 \times .476 \times .50}{2 \times .89} = 16 \times 10^3$$

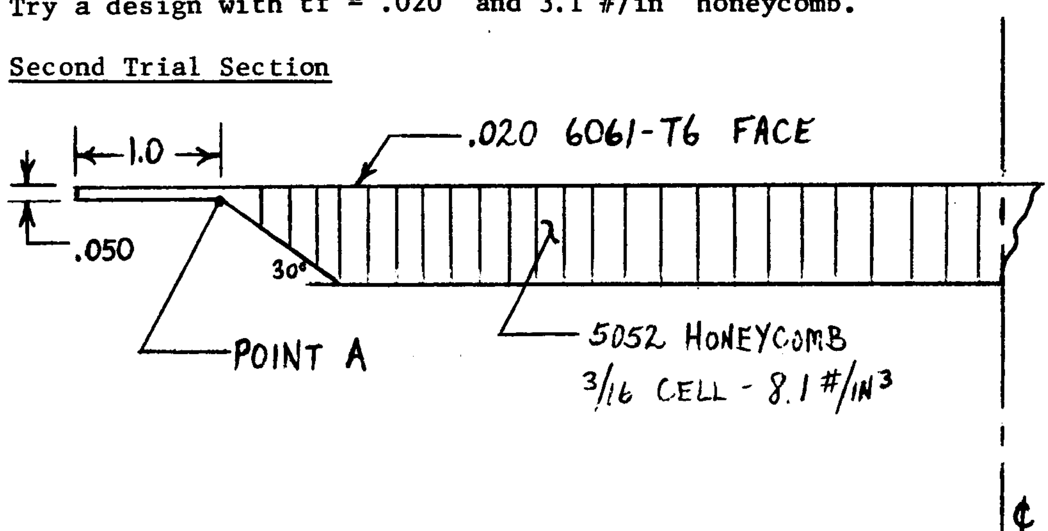
$$\delta = \frac{.01509 \times 1.5 \times 27.4^4}{16 \times 10^3} = .785 \text{ in. too high}$$

Determine the required D for $\delta = .150$ in.

$$D = \frac{.01509 \times 1.5 \times 27.4^4}{.150} = \underline{8.5 \times 10^4}$$

Try a design with tf = .020 and 3.1 #/in^2 honeycomb.

Second Trial Section



Loads due to the 1.5 PSI

$M_{℄}$ = 148 in-#/in $\quad M_{PTA}$ = 130 in^3/in

Required Section Modulus Z

$$Z_{℄} = \frac{M_{℄}}{f_{ty}} = \frac{.148 \text{ in-KIP/in}}{19 \text{ KSI}} = .0078 \text{ in}^3/\text{in}$$

$$Z_{PTA} = \frac{M_a}{f_{ty}} = \frac{.130}{19} = .00685 \text{ in}^3/\text{in}$$

Actual Section Modulus

$$Z_{\mathcal{C}} = \frac{t^3 - tc^3}{6t} = \frac{.5^3 - .46^3}{6 \times .5} = .009 \text{ in}^3/\text{in}$$

$$Z_{PTA} = \frac{.05^2}{6} = .00041 \text{ in}^2$$

Actual Stress

$$\sigma_{\mathcal{C}} = M/Z = .148/.009 = 16.5 \text{ KSI OK}$$

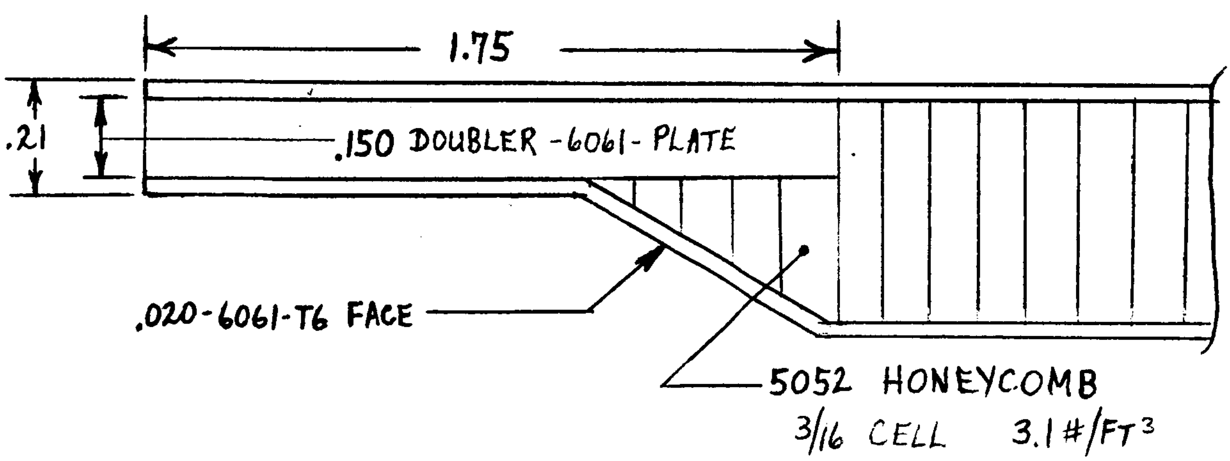
$$\sigma_{PTA} = M/Z_{PTA} = \frac{.130}{.00041} = 316 \text{ KSI No Good}$$

The required section modulus at point "A" is .00685 $\frac{\text{in}^3}{\text{in}}$

$$\frac{(tf)^2}{6} = .00685$$

$$tf = (.00685 \times 6)^{1/2} = .205 \text{ - Use } .21''$$

Third Trial Design



Facing Stress at ℄

$\sigma = 16.5$ KSI

M.S. $= \frac{19}{16.5} - 1 = 15\%$

Adequate M.S.
Use for floor panel

Facing Stress at point A

$= \frac{6 \times .130}{.21^2} = \frac{.78}{.0441} = 17.6$ KSI

M.S. $= \frac{19}{17.6} - 1 = +8\%$

Maximum Deflection at ℄

$\delta = \frac{\alpha_2 P a^4}{D}$ Ref. 3 Table 47

$D = 2.5 \times 10^4$ Ref. 4.2 Page 7

$a^4 = (27.4)^4 = 5.625 \times 10^5$

$\alpha_2 = 1.509 \times 10^{-2}$ Ref. 3 Table 47

$\delta = \frac{1.5 \times 10^{-3} \times 1.5 \times 5.625 \times 10^5}{2.5 \times 10^4} = \underline{\underline{.051 \text{ in}}}$ OK

Check Shearing Stress in the Core

$f_s = \frac{S}{a(t + tc)} = \frac{30.89 \times 1.5}{(.50 + .476)}$

$f_s = 47.5$ PSI

For 5052 - 3/16 core F_s min = 400 for 8.1 #/ft^3

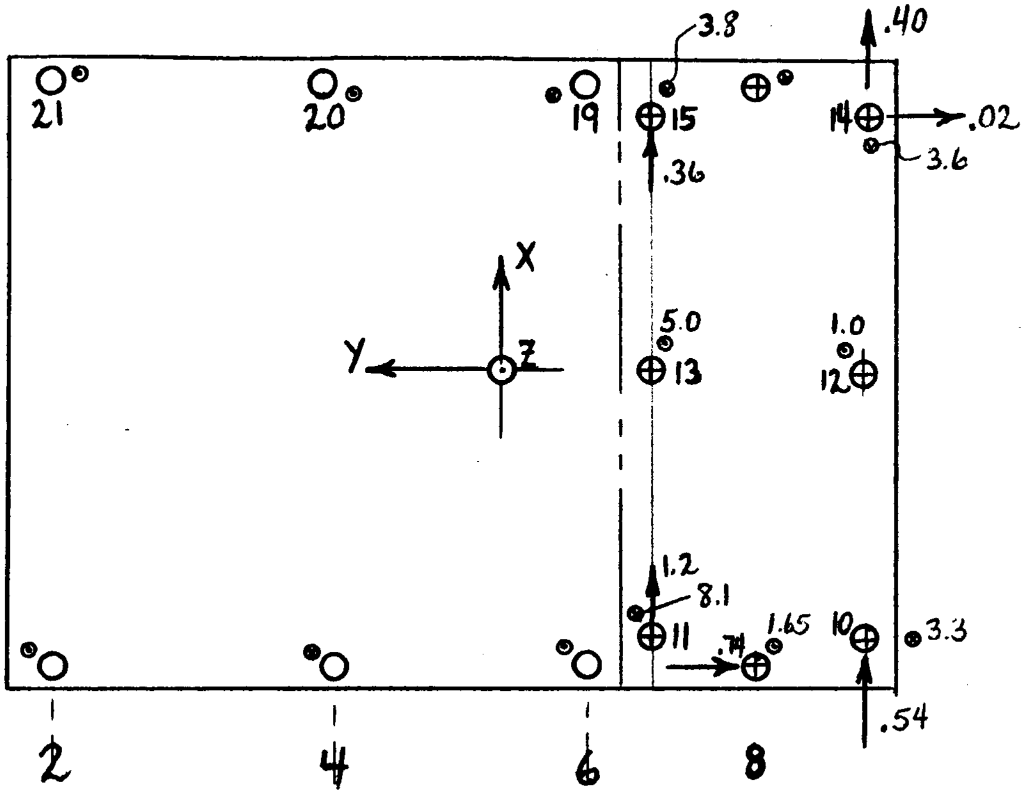
Use 5052 - 3/16 core F_s min = 88 for 3.1 #/ft^2

M.S. $= \frac{88}{47.5} - 1 = 85\%$

7.7 Support Bolt Analysis

View Looking Down

Loads shown per condition No. 1.



⊗ indicates tension in the bolt

⊙ indicate compression in the joint

Critical fastener #11

Shear = 1.2 KIPS, Tension = 8.1 K

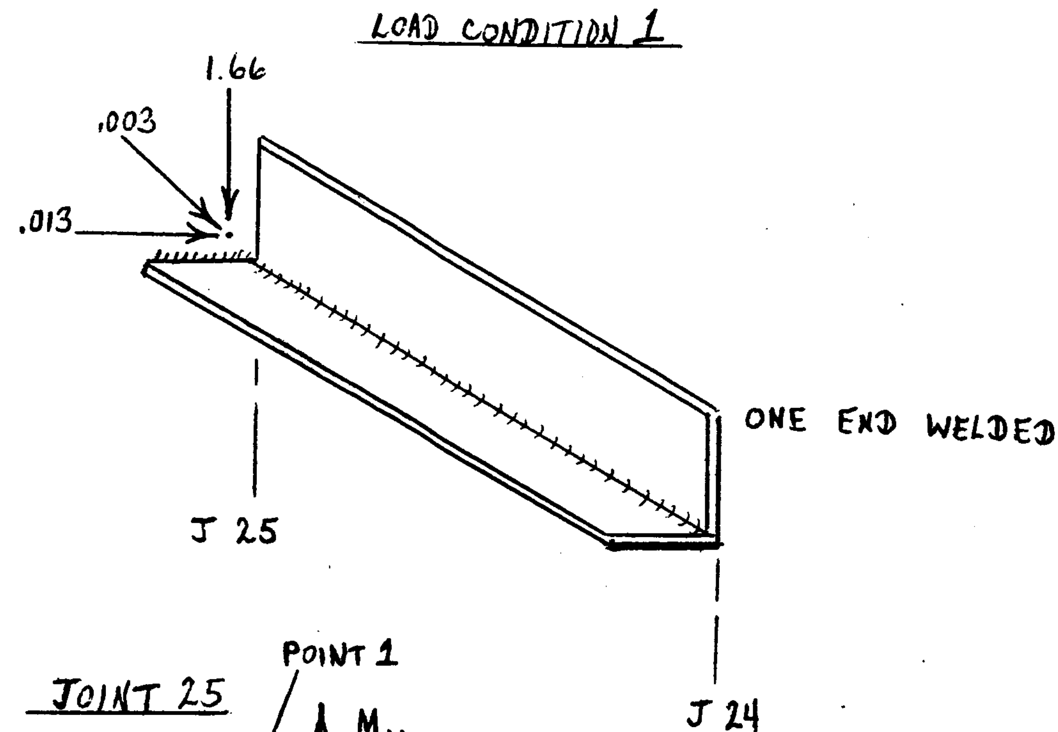
Use NAS 625- 180K HT - Bolts

T_{all} = 9 KIPS S_{All} = 8 KIPS

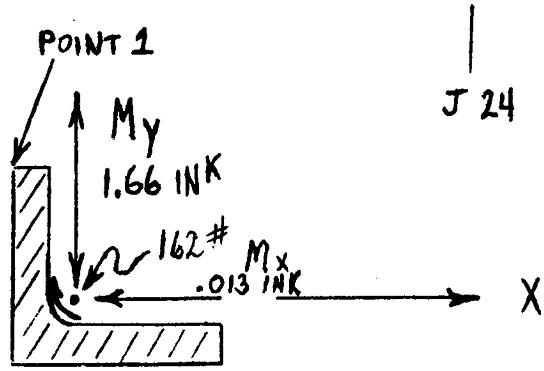
M.S. Adequate

7.8 Typical Bi-Axial Bending Analysis

A typical member which is subjected to a bi-axial loading condition is member 68 which spans between joints 25 and 24.



JOINT 25



$I_x = I_y = .059 \text{ in}^4$

$A = .43 \text{ in}^2$

$\bar{x} = \bar{y} = .37''$

$I \times Y = - .0319$

Coordinates point 1 $\quad x = - .37 \quad y = + .88$

Let:

$$K_2 = K_1 = \frac{I_{xy}}{I_x} = -.54$$

$$K_3 = 1 - K_1^{\,2} = .706$$

$$M_x^{\,1} = \frac{M_x + K_1 M_y}{K^3} = - .125 \text{ in K}$$

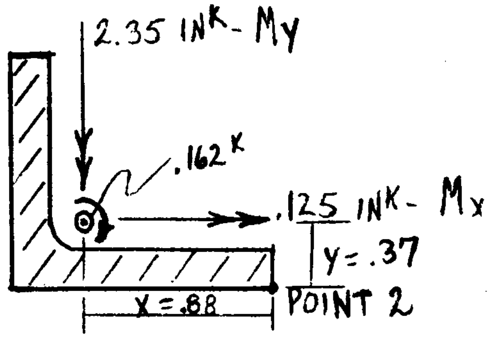
$$M_y^{\,1} = \frac{M_y + K_3 M_x}{K^3} = 2.35 \text{ in K}$$

7.8 Typical Bi-axial Bending (Cont'd)

The notations used on page are:

$M_x^1 \; M_y^1$ = Effective moments about the respective axis since the section is unsymmetrical

Cross section with effective bending moments applied:



Stress at Point 2

$$\sigma = \frac{P}{A} + \frac{M_{yx}}{I_y} - \frac{M_{xy}}{I_x}$$

$$\sigma = \frac{.162}{.43} + \frac{2.35 \times .88 - .125 \times .37}{.059} = 34.9 \text{ KSI}$$

$$\text{M.S.} = \frac{27}{34.9} - 1 = -22.5\%$$ IN WELDED ZONE

M.S. in non-welded zone

$$\text{M.S.} = \frac{38}{34.9} - 1 = +9\%$$

8.0 Equipment Mounting

The shower facility is supported by a self contained equipment compartment. The upper half houses the electrical systems while the lower half houses the mechanical systems.

Major components. Those which have a weight greater than 6# at one-G have a structural load path provided those under 6# are mounted with good judgement.

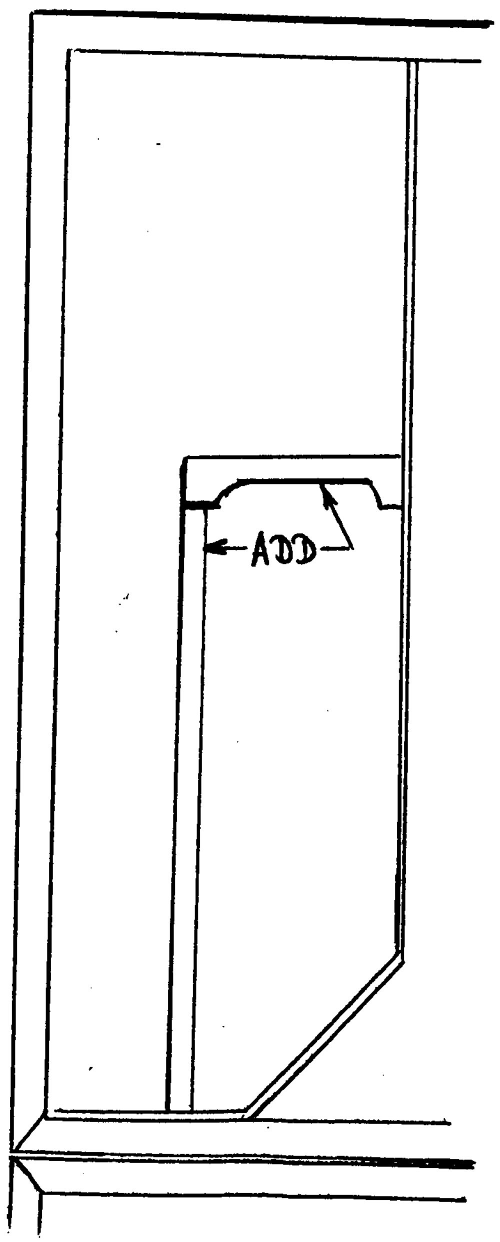
8.1 Electrical Equipment Mounting - Reference Dwg. 89900000881 for electrical installation.

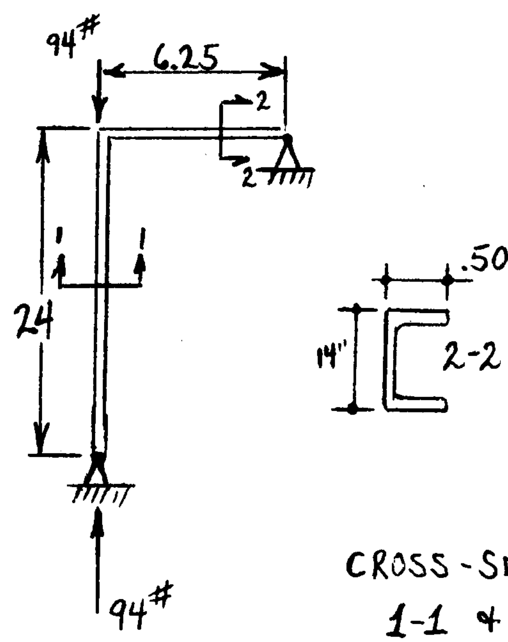
Add the support shown .063-6061-0 heat treat to T651 cond. connect to existing bracket assy. with MS20420-5 rivets.

Max. load in added plate 6.25 + 4 + 4 + 3 = 19.25# at 10G

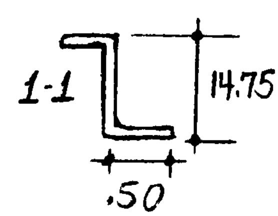
Vert = 193#

Assume 1/2 per support 193/2 = 94#





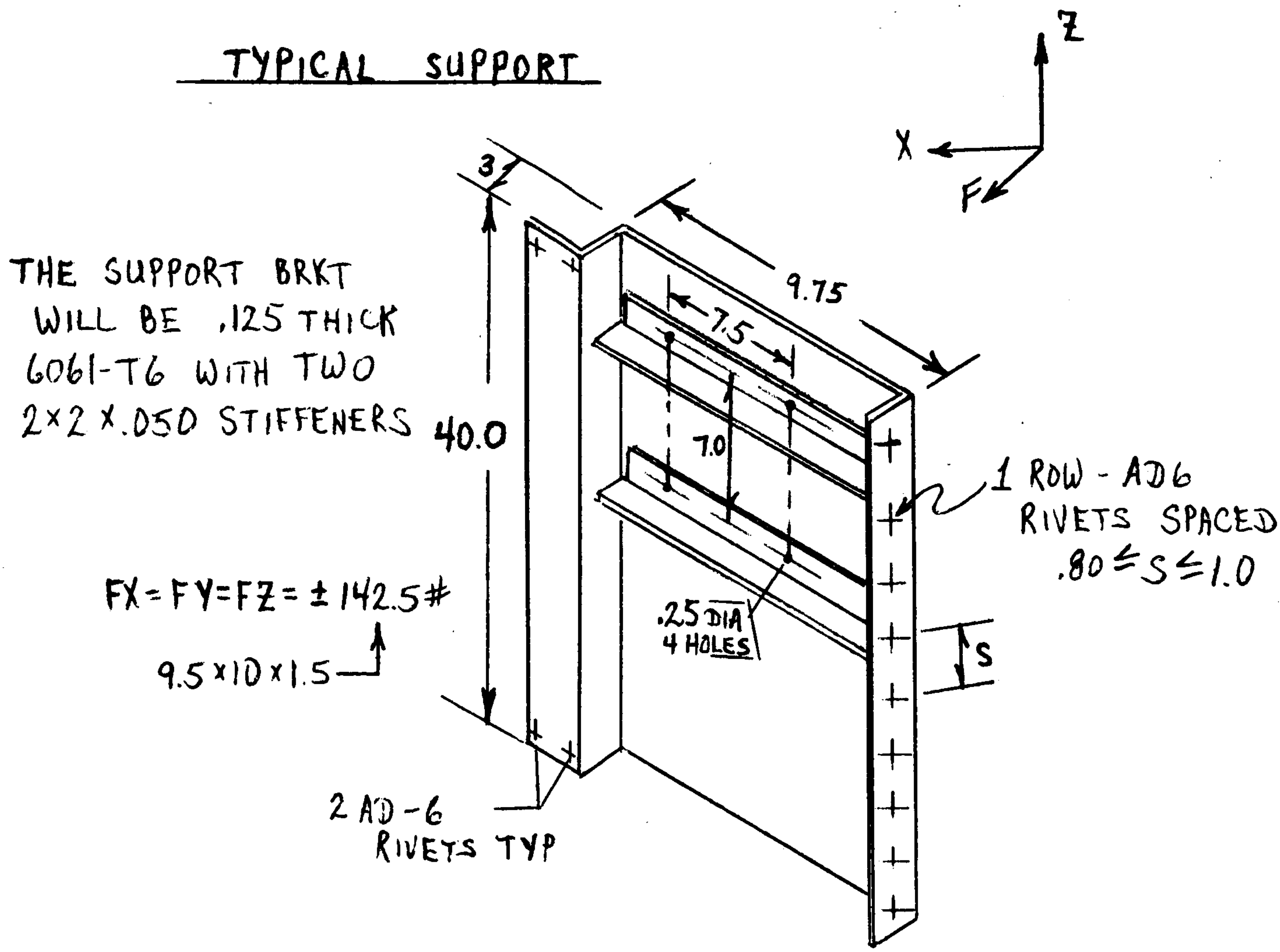
CROSS-SECTIONS
1-1 + 2-2
ADEQUATE



8.2 Fluid Components - The maximum weighted mechanical component is the vortex liquid gas separator which is designed to withstand 10 g's in any direction. It's estimated weight is 9.5 pounds.

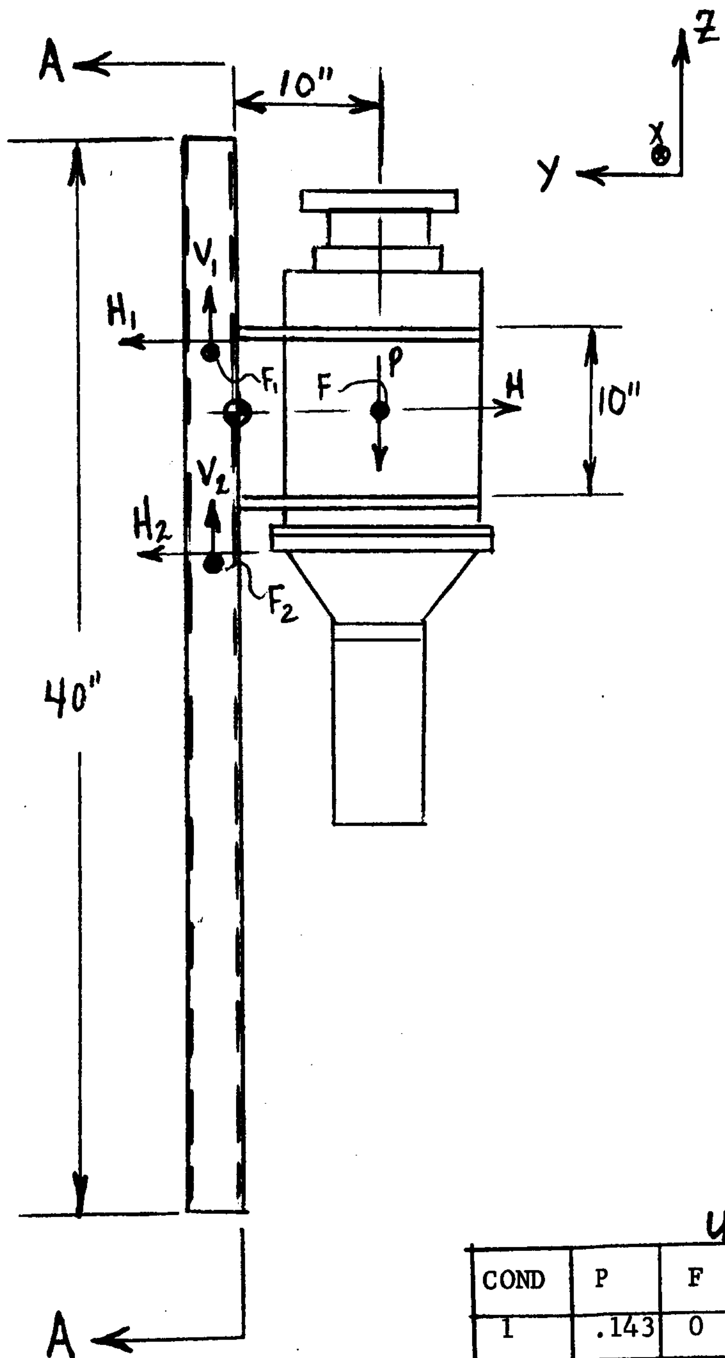
The support bracket for the separator will be designed for the following load in the structural axis system - See page for sign convention

TYPICAL SUPPORT



Separator Support Bracket Analysis

Reference Dwg. 89900000868



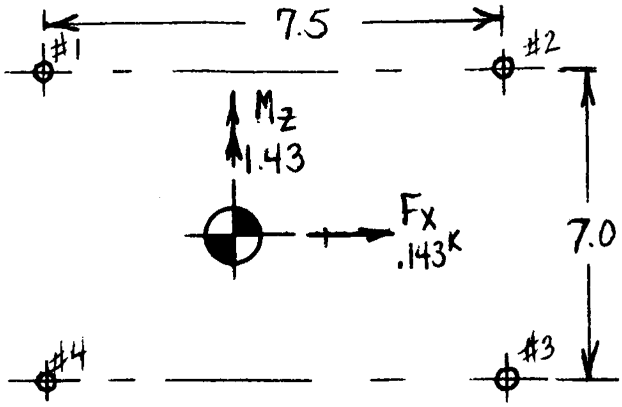
CENTROID OF FASTENER PATTERN

SEE NEXT PAGE FOR A-A

ULT LOAD IN KIPS

COND	P	F	H	F_x	F_y	F_z	M_x	M_y	M_z
1	.143	0	0	0	0	-.143	-1.43	0	0
2	0	.143	0	.143	0	0	0	0	1.43
3	0	0	.143	0	.143	0	0	0	0

Bolt loads Ref. cut A-A Page



LOAD COND. 2

BY SYM.

$$F1 = F2 = F3 = F4 = \frac{.143}{4} = .0358^K$$

$$F2Y = F3Y = -F1Y - F4Y = \frac{1.43}{2 \times 7.5} =$$

$F2Y = .095^K$ TENSION

By inspection a .25 dia bolt will transmit without deformation a shear of 36# combined with 95# tension. Bearing in .125 matl. The .25 bolt can bear up with a maximum of 3 KIPS. M.S. adequate.

Check the Buckling of the Basic Bracket - .125

Max. plate width = 9.75" - see sketch - page

$$b/t = \frac{9.75}{.125} = 78 \; : \; \sqrt{\frac{F_{cy}}{E}} = .059 \text{ see page}$$

$$78 \times .059 = 4.6 \qquad \frac{F_{cc}}{F_{cy}} = .48 \quad \text{no edge free}$$

All compression stress = $.48\ F_{cy}$ = 16.8 KSI F_{cc}

$$f_{cc} = \frac{P}{A} = \frac{142.5}{9.73 \times .125} = .118 \text{ KSI} \qquad \text{M.S.} \gg 1.0$$

9.0 References

1.0 MCR 72-154 "Preliminary Design Review on SSP Zero Gravity Whole Body Shower" June 1972.

2.0 NASA SP-3006 "Bioastronautics Data Book" 1964.

3.0 Theory of Plates and Shells" - By "S. Timoshenko, Woinowsky, Krieger", 1959.

4.0 Honeycomb Sandwich Design by Hevcel

4.1 Brochure "E"

4.2 TSB 121 June 1966

4.3 TSB 120 Jan. 1966

5.0 Structural Aluminum Design-Reynolds, 1968.

6.0 "Buckling Strength of Metal Structures: by F. Bleich. McGraw Hill, 1952.

APPENDIX E

NON-METALLICS MATERIALS LIST

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN: SSP-7500
PAGE 1 OF 1

SUBSYSTEM: ZERO GRAVITY WHOLE BODY SHOWER	DATE: April, 1973
COMPONENT: SHOWER STALL ASSEMBLY	ITEM NO.:
DRAWING NO.: 89900000870	REQUESTING ORGANIZATION: MARTIN MARIETTA AEROSPACE
	SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher

CSD MRB APPROVAL (Concurrence)

CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN²)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
1		COATING TEFLON S	E. I. DUPONT	958-200	Coating (3 mil) on interior walls of stall	A	7.0-14.7 PSIA, 3.5 PSIA O_2, 70-110°F, 55%-85% RH		11,400				
2		SILICONE GASKET			Seal between stall halves	A	Cabin Ambient, As Above		8.25 Edge				Gasket Sealed Between Metal Flanges (Heat Sink) on Stall Halves.
3		LEXAN	GENERAL ELECTRIC	9030-112	Shower Door	A	Cabin & Stall Ambient		1800 2sides				Attached to Metal Door Frame, Trimmed Flush.
4		SEAL, SILICONE	R. E. DARLING	A10041-5	Seal on Door Edge	A	Cabin & Stall Ambient		75				Generally Sealed Between Metal-Door Frame & Metal Shower Structure
5		ADHESIVE, SILICONE	DOW CORNING	Silastic RTV 732	Bonds Seals to Frame	B	Cabin & Stall Ambient		<5				Used on Door Seal and On One Side of Stall Flange Gasket-Exposed
6		LEXAN	G. E.	9030-112	Light Cover in Stall Ceiling	A	Cabin & Stall Ambient		392				
7		FLUOREL GASKET		MMA-MMSC440	Seal in Light Cover Assy.	A	Cabin & Stall Ambient		200				Sealed Between Lexan Cover And Metal Stall
8		SILICONE GASKET		MMA-MMSC120	Seal on Handrail Assy in Stall	B	Cabin & Stall Ambient		1				Edge only Exposed, Sealed Between Metal Handrail Flange & Stall
9		LIGHT BULB, FL. (4)	G. E. 5106WW	GLASS	Four-6 Watt Bulbs in Stall Ceiling	A	Cabin & Stall Ambient		60				
10		LEXAN	G. E.	2014	Prin. Material In Lamp Holders (8)	A	Cabin & Stall Ambient		20				Enclosed Behind Lexan Light Cover
11		TEFLON	DUPONT	TFE	Used for Soap Pkg. Holder & Hose Retainer	A	Cabin & Stall Ambient		30				
12		SILICONE GASKET		MMA-MMS C 120	Seal @ Vac. Hose & Water Hose/Stall Interface	A	Cabin & Stall Ambient		1				See Item 8, Trimmed Flush
13		POLYURETHANE COATING		MMA-STP 30136KK7381	Coating (10Mils) on Outer Stall & Structure	A	Cabin & Stall Ambient		20,000				

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN SSP-7501

PAGE 1 OF 1

SUBSYSTEM: ZERO GRAVITY WHOLE BODY SHOWER

DATE: April, 1973

CSD MRB APPROVAL (Concurrence)

COMPONENT: Liquid Level Sensor (4)

ITEM NO.:

REQUESTING ORGANIZATION: Martin Marietta Aerospace

DRAWING NO.: 89900000861-063

SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher

CHAIRMAN:

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN²)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
14		Wire Insulation TFE Teflon	E.I. DuPont	TFE	Wire Insulation	B&Z	Cabin ambient	0.01	1				
15		Tubing	E.I. DuPont	TFE	Covering over probes	B&Z	Cabin ambient	0.01	1				
16		Potting Compound	Emerson & Cuming	Stycast 2850 Epoxy	Potting Compound	Z	Cabin ambient						Item 16 enclosed in SS body, Other material data unknown.
16A		LLS Control Circuit					Cabin Ambient						Specific materials used in the LLS control circuit are unknown but are contained within the alum housing mounted behind the LGS, materials used in the LLS power pack, mounted within the elec. box, are also unknown

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN SSP-7502

SUBSYSTEM: Zero Gravity Whole Body Shower	DATE: April, 1973	CSD MRB APPROVAL (Concurrence)
COMPONENT: Mass Flowmeter & Signal Cond. (1" & 2") ITEM NO.	REQUESTING ORGANIZATION: Martin Marietta Aerospace	
DRAWING NO.: 89900000861-011 & -031,-071,-073,-075,-077	SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher	CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN²)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
17		Plastic		High impact thermosetting	Insert insulation of switchcraft 44F conn.	B & Z	Cabin ambient	0.01	1				Enclosed in zinc conn. shell Connector always mated. Items17-36,, Excl. 18 & 24 are enclosed in metal box contained in ZGWBS Elec. Box (closed, not sealed)
18		Plastic		Neoprene	Cable relief bushing on conn.	B & Z	Cabin ambient	0.1	2				Enclosed in zinc shell Connector always mated.
19		Light, Indicator	DELETED	Tineon 3600 Leecraft	Indicator light on meter panel	B & Z	Cabin ambient	0.1	1				Material unknown. No material data See Dwg 89900000880
20		Connector		Amp 143-022-03	Printed circuit connector	B & Z	Cabin ambient	0.1	1				Material unknown Connector always mated.
21		Transformer		Grand 1097715		A,Z,F	Cabin ambient						Material unknown. Items 26-41 are enclosed in metal housing.
22		Wire		Dearborn		B,Z,F	Cabin ambient						Insulation material unknown
23		Meter, Panel		API 502		A,Z,F	Cabin ambient						Materials unknown
24		Fuse Holder		Busman HKP		B,Z,F	Cabin ambient						Materials unknown
25		Barrier Strip		Cinch-Jones 2-140Y		B,Z,F	Cabin ambient						Materials unknown
26		Thermistors		Veco 41A5, 45A23		B,Z,F	Cabin ambient						Materials unknown
27		Printed Circuit	Synthan Taylor		Printed circuit material	A,Z,F	Cabin ambient						Quantity and material unknown
28		Diode		B5E5 EDAL		B,Z,F	Cabin ambient						Quantity and material unknown
29		Diode		1N821 Centralab		B,Z,F	Cabin ambient						Quantity and material unknown
30		Diode		1N4744A MOT		B,Z,F	Cabin ambient						Quantity and material unknown
31		Capacitors		Sprage TVA 1422		B,Z,F	Cabin ambient						Quantity and material unknown

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN SSP-7502

SUBSYSTEM: Zero Gravity Whole Body Shower

DATE: April, 1973

COMPONENT: Mass Flowmeter & Signal Cond. (1" & 2")

ITEM NO.:

REQUESTING ORGANIZATION: Martin Marietta Aerospace

DRAWING NO.: 89900000861-011 & -031,-073,-075,-077

SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher

CSD MRB APPROVAL (Concurrence)

CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN^2)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
32		Power Resistors		Sprage 452E515		B,Z,F	Cabin ambient						Quantity and material unknown
33		Metal Film Resistor		RNGOD, IRC, DAWE, MEPCO		B,Z,F	Cabin ambient						Quantity and material unknown
34		Amplifiers		Analog Device 118A		B,Z,F	Cabin ambient						Quantity and material unknown
35		Potentiometers		RC 205-218 or Daystrom 552-00		B,Z,F							Quantity and material unknown
36		Transistors		2N1132 Tex. Ins.		B,Z,F							Quantity and material unknown Line Nos. 17 thru 36 are included in both the 1" & 2" units
36A		Grommet				B,Z	Cabin Ambient						Used on elec. conn between flowmeters & signal conditioner, one on each side, each flowmeter conn. - Total 4 - material unknown

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN SSP-7503

PAGE 1 OF 1

SUBSYSTEM: Zero Gravity Whole Body Shower

COMPONENT: Duct Assy., Heater to Stall

ITEM NO.:

DRAWING NO.: 89900000861-185, 89900000886

DATE: April, 1973

REQUESTING ORGANIZATION: Martin Marietta Aerospace

SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher

CSD MRB APPROVAL (Concurrence)

CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN²)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
37		Flex Tube	Penntube Plastics	Teflon TFE	Elbow between heater & stall	A	Air - $100^{\circ}F$ Cabin ambient	1	150				

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD (CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN SSP-7504

SUBSYSTEM: Zero Gravity Whole Body Shower
DATE: April, 1973
COMPONENT: Elec. System
ITEM NO.:
REQUESTING ORGANIZATION: Martin Marietta Aerospace
DRAWING NO.: 8990000088 1
SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher
CSD MRB APPROVAL (Concurrence)
CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN²)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
38		Wire Insulation	MIL-W-16878	TFE Teflon	Jacket over wire	A	Cabin ambient		2200				1400 in^2 unshielded (400ft), 800 in^2 shielded (100 ft)
39		Epoxy, Mineral Glass-Filled			Insulator	Z	Cabin ambient						Line Nos. 39 thru 43 refer to elec. connectors (37 total). All conn. are
40		Elastomer, Silicone Rubber	ITT Cannon Blend		Grommets, Interfacial & o-ring seals	Z	Cabin ambient						always mated, meet NAS 1599.
41		Lubricant	MIL-L-8937	Dry solid lubricant	Internal cam groove of coupling nut	Z	Cabin ambient						
42		Adhesive		High temp epoxy		Z	Cabin ambient						
43		Marking Ink				Z	Cabin ambient						
44		Circuit Breakers (2)	(JA1-W3-S-2-BLHN) Heinemann			Z	Cabin ambient						Specific material data unknown for line nos. 44 thru 58 All items
45		Circuit Breakers (2)	(JA3-W3-S-2-BLHN) Heinemann			Z	Cabin ambient						except nos. 53-55 enclosed in metal elec. box.
46		Circuit Breaker	(JA1-W3-75-2) Heinemann			Z	Cabin ambient						
47		Circuit Breaker, main	(JA3-C16C3C3-A) Heinemann			Z	Cabin ambient						
48		Current Sensors (2)	American Aerospace Cont. Series1004M4-5			Z	Cabin ambient						
49		Relays, Solid State AC(10)	Teledyne 602-10013			Z	Cabin ambient						
50		Relay, Solid State DC	Teledyne 602-10012			Z	Cabin ambient						
51		Toggle Switch	Carlingswitch2FA64			Z	Cabin ambient						
52		Toggle Switch	CarlingswitchHK254			Z	Cabin ambient						
53		Rotary Switch	Knob 1 Carlingswitch700-12			Z	Cabin ambient						
54		Thermocouple	Athena 700-J			Z	Cabin ambient						

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN SSP-7504

SUBSYSTEM: Zero Gravity Whole Body Shower

DATE: April, 1973

COMPONENT: Elec. System (continued)

ITEM NO.:

REQUESTING ORGANIZATION: Martin Marietta Aerospace

DRAWING NO.: 89900000881

SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher

CSD MRB APPROVAL (Concurrence)

CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN²)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
55		Temp. Sensor	Tylan RP-050			Z	Cabin ambient						Specific material data unknown
56		Transformer (18)	Abbott 2E5CT			Z	Cabin ambient						
57		Resistors			Used in conjunction with relays	Z	Cabin ambient						
58		Relay	Teledyne 602-10014			Z	Cabin ambient						
59		Nylon Insulation			Insulation on terminal lugs	B	Cabin ambient						Enclosed in elec. box, used on Skylab T027, 899T0270280,0270, discussed with Dale Sauer (NASA-JSC) 2/21
60		Grommet, Nylon	Russell Ind.	Cat-2A, 3A	Protects wire harnesses passing thru elec. box	A	Cabin ambient						
60A					Wire Markers	B	Cabin Ambient						Used in approx 50 locations
60B		Nylon			Wire Bundle Ties	B	Cabin Ambient						Used in approx 100 locations

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD (CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN: SSP-7505

SUBSYSTEM: Zero Gravity Whole Body Shower	DATE: April, 1973
COMPONENT: Vacuum Pickup & Water Hose Assembly — ITEM NO.:	REQUESTING ORGANIZATION: Martin Marietta Aerospace
DRAWING NO.: 89900000883, 4	SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher

CSD MRB APPROVAL (Concurrence)

CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN^2)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
61		Teflon TFE	E. I. DuPont			A	Shower ambient		40				DELETED
62		Silicone Rubber		MMA-MMSC 120	Squeegee on front of pickup head	A	Shower ambient	.2	10				
63		Polyurethane Coating		STP 30136, K738J	Coating on pickup head body	A	Shower ambient	.2	12				
64		Silicone	R. E. Darling A 10985-1	SI-503	Flexible hose on vacuum pickup hose stall to head	A	Shower ambient	2	283(in) 368(out)				
65		Silicone	R. E. Darling A 10545-3	SI-503	Hose clamp cover-molded	A	Shower ambient	.2	11				
66		Silicone	R. E. Darling A 10318-5	SI-503	Water hose in stall	A	Shower ambient 28 psig H_2O	.6	156(outside)				Hose constantly pressurized at 28 psig
67		Silicone	R. E. Darling A 10545-18	SI-503	Flexible hose from vac. pickup to LGS inlet	A	Shower ambient		50(in) 60(out)				

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD (CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN: SSP-7506

SUBSYSTEM: Zero Gravity Whole Body Shower

COMPONENT: Liquid/Gas Separator

ITEM NO.:

DRAWING NO.: 89900000897

DATE: April, 1973

REQUESTING ORGANIZATION: Martin Marietta Aerospace

SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher

CSD MRB APPROVAL (Concurrence)

CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN²)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
68		Sheet, Plastic	General Electric	Lexan 9030-112	LGS body-total unit	A	0.3 gpm H_2O 30 cfm air inlet ambient press	6.5	4000				Standard Lexan 9030- in place of 9600
69		Solvent		Tetrahydrofuran-THF	Bonding agent for LGS parts	A	Same as above		62				
70		Tape, Teflon	Kaufman Glass Co.		Thread sealant on liquid level sensor probes	B	Shower ambient	0.01	2				
71		O-Ring	Parker Seal - MS9068-229	S-604-7	Seal at top of sump	B	Shower ambient	0.01					Enclosed within LGS parts (Lexan)
72		O-Ring	Parker Seal - MS9068-240	S-604-7	Seal at air out-let	B	Shower ambient	0.01					Sealed within LGS parts (Lexan)
73		O-Ring	Parker Seal - MS9068-261	S-604-7	Seal above coni-cal section of LGS	B	Shower ambient	0.01					Sealed within LGS parts (Lexan)
74		Gasket, Silicone	Parker Seal - MS9068	S-604-7	Seal at 20 inlet flange	B	Shower ambient		23 (tot) 1.3 (edge)				Only edge exposed to atmosphere
75		Gasket, Silicone	Parker Seal - MS9068	S-604-7	Seal at air in-jection inlet flange	B	Shower ambient		14 (tot) 1.0 (edge)				Only edge exposed to atmosphere
76		O-Ring (2), Buna-N			Seal on CPV fitting at H_2O-out and panel	B	Water line		1				
76A		Epoxy, Two part	Dupont		Seal Flange at LGS Sump	B	Cabin Ambient		≈ 2				

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

M.N SSP-7507

PAGE 1 OF 1

SUBSYSTEM: Zero Gravity Whole Body Shower

DATE: April, 1973

COMPONENT: Water Spray Nozzle & Valve

ITEM NO.:

REQUESTING ORGANIZATION: Martin Marietta Aerospace

DRAWING NO.: 89900000885

SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher

CSD MRB APPROVAL (Concurrence)

CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN^2)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
77		Phenolic, Black	Durez 13856	Molding Compound Durez 13856	Hand-held valve body	A	Shower ambient 28 psi H_2O	0.5	18(outside)				Internal surfaces always pressurized with H_2O
78		O-Ring			Seal at plunger	B	Shower ambient 28 psi H_2O	.01	.1				Dynamic seal, material unknown
79		O-Ring, Silicone		MMA-MMS C120	Seal at water hose interface	B	Shower ambient 28 psi H_2O	.01	.1				
80		Washer, Silicone		MMA-MMS C120	Seal at plunger base-poppet seal	B	28 psi H_2O	0.01	.1				Enclosed in handle; spring & water pressure constantly applied

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN SSP-7509

SUBSYSTEM Zero Gravity Whole Body Shower	DATE April, 1973	CSD MRB APPROVAL (Concurrence)	
COMPONENT Soap System	ITEM NO.	REQUESTING ORGANIZATION Martin Marietta Aerospace	
DRAWING NO. 89900000892			
	SUBSYSTEM MANAGER (OR DESIGNEE) E. A. Schumacher		CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN^2)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
82		Soap, Neutrogena	Neutrogena	Rainbath, Unscented	Cleansing Agent	A & Z	Shower ambient	36 (soap)					Packaged in alum. foil-1080-15GM Ea.
83		Packages (1080)	Supplied by Neutrogena	Continental Can-CC2				40	27000				Outer-50GA Milar, .00035 alum. foil. Inner - .0015 polypropylene - Pkgs. enclosed in SSP supplied container

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN SSP-7510

SUBSYSTEM: Zero Gravity Whole Body Shower

DATE: April, 1973

COMPONENT: Water Flowmeter-Totalizer, Transmitter

ITEM NO.:

REQUESTING ORGANIZATION: Martin Marietta Aerospace

DRAWING NO.: 89900000861-001, -067, -065, -085, & -105

SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher

CSD MRB APPROVAL (Concurrence)

CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN²)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
84		O-Ring-CPV, Buna-N (2)			Seals on H_2O lines at inlet & outlet	B	H_2O-28 psig	0.01	.2 ea				Exposed to air only during maintenance
85		Elec. Conn., Female	MIL-C-5015	MS-3106E-10SL-3S	Conn. between trans. & signal conditioner								Not defined, all conn. always mated - line nos. 85 & 86
86		Elec. Conn., Male	MIL-C-5015	MS-3106E-10SL-3P									
87		O-Ring, Buna-N	Parker Seal	N552-9	Seal in flowmeter	B,F,Z		0.01	0.1				Enclosed in SS body
88		Barrier Block	Simmond's Precision 4880017		Support on back plate of totalizer	F,Z	Cabin ambient	0.1	10				Items 88 thru 92 enclosed in metal case, specific materials
													unknown, contained in metal ZGWBS elec. box
89		Fuse Holder	Simmond's Precision 4880014		Fuse holder at back plate	F,Z	Cabin ambient	0.1	10				
90		Fuse	Simmond's Precision 4880015		Fuse in totalizer	F,Z	Cabin ambient	0.01	2				
91		Printed Circuit Board	Simmond's Precision 4806037		Power supply P/C Assy in totalizer	F,Z	Cabin ambient	0.1	50				
92		Printed Circuit Board	Simmond's Precision 4806033		Main P/C assy in	F,Z	Cabin ambient	0.1	50				

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN: SSP-7510

PAGE 2 OF 2

SUBSYSTEM: Zero Gravity Whole Body Shower

DATE: April, 1973

COMPONENT: Water Flowmeter-Totalizer, Trans & Elec. Conn

ITEM NO.:

DRAWING NO.: 89900000861-001, -067, -065, -085 and -095

REQUESTING ORGANIZATION: Martin Marietta Aerospace

SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher

CSD MRB APPROVAL (Concurrence)

CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN^2)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
93		Transformer	Simmond's Precision 4825004		Transformer in totalizer	F,Z	Cabin ambient	1.0	20				Specific materials unknown
94		Lamp Assembly	Simmond's Precision 4826006		Lamp assy at front of totalizer	Z	Cabin ambient	0.1	5				Specific materials unknown
95		Meter	Simmond's Precision 4878010		0.1 MA D.C. meter in totalizer	Z	Cabin ambient	0.5	20				Specific materials unknown

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN SSP-7511

PAGE 1 OF 1

SUBSYSTEM: Zero Gravity Whole Body Shower	DATE: April, 1973	CSD MRB APPROVAL (Concurrence)
COMPONENT: Main Air Flow Line - Blower to Flowmeter / ITEM NO.	REQUESTING ORGANIZATION: Martin Marietta Aerospace	
DRAWING NO.: 89900000861-015, 89900000886	SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher	CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN²)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
96		TFE Teflon Tube	Penntube Plastics	TFE	Main air flow line	A	Ambient Air	0.5	250				

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN SSP-7512

PAGE 1 OF 1

SUBSYSTEM: Zero Gravity Whole Body Shower		DATE: April, 1973	CSD MRB APPROVAL (Concurrence)
COMPONENT: Main Air Flow Line - LGS Outlet to Blower	ITEM NO.	REQUESTING ORGANIZATION: Martin Marietta Aerospace	
DRAWING NO. 89900000888		SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher	CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN^2)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
97		Teflon Tube	Penntube Plastics	TFE	Flex air from LGS outlet to blower	A	Cabin ambient	0.5	250				

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD (CSD/MRB) NONMETALLIC MATERIALS MASTER LOG (Prepare in Triplicate)	MLN SSP-7513 PAGE 1 OF 1

SUBSYSTEM Zero Gravity Whole Body Shower	DATE April, 1973	CSD MRB APPROVAL (Concurrence)
COMPONENT Time Meter / ITEM NO.	REQUESTING ORGANIZATION Martin Marietta Aerospace	
DRAWING NO. 89900000861-023	SUBSYSTEM MANAGER (OR DESIGNEE) E. A. Schumacher	CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN^2)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
98		Plastic, Acetal Homopolymer	E. I. DuPont	Delrin	Wheels, Internal	B,Z	Cabin ambient						Items 98-102 contained in metal ZGWBS Electrical Box
99		Gears		Nylatron	Spur Gears	B,Z	Cabin ambient						
100		Motor	Luxtime Div. Model Robertshaw 225			Y							Specific material data unknown for line nos.
101		Label	Avery Ceramatic Vinex P5										
102		Nameplate, Lithographic Ink											

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN SSP-7514

SUBSYSTEM: Zero Gravity Whole Body Shower

DATE: April, 1973

CSD MRB APPROVAL (Concurrence)

COMPONENT: Watthour Meter

ITEM NO.

REQUESTING ORGANIZATION: Martin Marietta Aerospace

DRAWING NO.: 89900000861-021,

SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher

CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN²)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
103		Plug, Hole	Cinch Jones-41A			B,Z	Cabin ambient						Items 103 thru 157 are part of commercial unit, specific matl data unknown. Enclosed in metal housing contained in metal ZGWBS elec. box.
104		Circuit Board	Sci.Col. B2193			Z	Cabin ambient						
105		Circuit Board, Printed	Sci.Col. 2000C Harrison			Z	Cabin ambient						
106		Transformer Assy.	Scientific Columbus 112-201			Z	Cabin ambient						
107		Insulation	Core-Iu-375-C422-H14Y3		Core insulation in transformer coil	Z	Cabin ambient						
108		Bobbin	Sci.Col. 5658			Z	Cabin ambient						
109		Capacitor	Sci.Col. 39D2576075 JE4,250MFD/75V Sprague			Z	Cabin ambient						
110		Capacitor	82PFD/1KV Disc			Z	Cabin ambient						
111		Capacitor	39MFD/10V Sprague			Z	Cabin ambient						
112		Capacitor	22MFD/15V Sprague			Z	Cabin ambient						
113		Diode	Sci.Col. KBP 02			Z	Cabin ambient						
114		Diode	Sci.Col. IN458			Z	Cabin ambient						
115		Diode	Sci.Col. IN753A			Z	Cabin ambient						
116		Diode	Sci.Col. IN5243-A			Z	Cabin ambient						
117		Transistor	Sci.Col. 2N3904			Z	Cabin ambient						
118		Transistor	Sci.Col. 2N3906			Z	Cabin ambient						
119		Transistor	Sci.Col. 2N4922 Motorola			Z	Cabin ambient						

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN SSP-7514

SUBSYSTEM: Zero Gravity Whole Body Shower

DATE: April, 1973

CSD MRB APPROVAL (Concurrence)

COMPONENT: Watthour Meter (continued)

ITEM NO.

REQUESTING ORGANIZATION: Martin Marietta Aerospace

DRAWING NO.: 89900000861-021.

SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher

CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN²)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
120		Transistor FET	National Sci.Col. 2N4091			Z	Cabin ambient						Items 103 thru 157 are part of commercial unit, specific matls data unknown. Enclosed in metal housing, contained in metal ZGWBS elec. box.
121		Transistor FET	Amelco Sci.Col. P1086-E			Z	Cabin ambient						
122		Resistor	Sci.Col. RN60D 2.21K ohms			Z	Cabin ambient						
123		Resistor	Sci.Col. RN60D 3.32K ohms			Z	Cabin ambient						
124		Resistor	Sci.Col. RN60D 10K ohms			Z	Cabin ambient						
125		Resistor	Sci.Col. RN60D 1.4K ohms			Z	Cabin ambient						
126		Resistor	Sci.Col. RN60D 5.11 ohms			Z	Cabin ambient						
127		Resistor	Sci.Col. RN60D 1K ohms			Z	Cabin ambient						
128		Resistor	Sci.Col. RN60C 487 ohms			Z	Cabin ambient						
129		Resistor	Sci.Col. RN60D 1.05K ohms			Z	Cabin ambient						
130		Circuit Board Assy.Poten.	Sci.Col. B2192			Z	Cabin ambient						
131		Circuit Board, Printed	Sci.Col. B2003C Harrison			Z	Cabin ambient						
132		Transformer Assy.	Sci.Col. A112-170			Z	Cabin ambient						
133		Capacitor	Sci.Col. Tel 1211 100 MFD 25V			Z	Cabin ambient						
134		Capacitor	220 PFD 1KV Disc			Z	Cabin ambient						
135		Capacitor	.005MFD 1KV Disc			Z	Cabin ambient						
136		Capacitor	Sci.Col. 192P22392 .022 MFD 200V Sprague			Z	Cabin ambient						

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN SSP-7514

SUBSYSTEM: Zero Gravity Whole Body Shower

DATE: April, 1973

CSD MRB APPROVAL (Concurrence)

COMPONENT: Watthour Meter (continued)

ITEM NO.

REQUESTING ORGANIZATION: Martin Marietta Aerospace

DRAWING NO.: 89900000861-021,

SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher

CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN²)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
137		Capacitor	Sci.Col. 225PZ 75V,0.22MFD Sprague			Z	Cabin ambient						Line nos 103 thru 157 are part of commercial unit, specific matl data unknown. Enclosed in metal housing, contained in metal ZGWBS elec. box.
138		Diode	Sci.Col. IN458			Z	Cabin ambient						
139		Diode	Sci.Col. IN754			Z	Cabin ambient						
140		Diode	Sci.Col. IN753A			Z	Cabin ambient						
141		Resistor	Sci.Col. RN60C 49.9 ohms			Z	Cabin ambient						
142		Resistor	Sci.Col. RN60C 69.8 ohms			Z	Cabin ambient						
143		Resistor	Sci.Col. RN60C 10K ohms			Z	Cabin ambient						
144		Resistor	Sci.Col. RN60D 10K ohms			Z	Cabin ambient						
145		Resistor	Sci.Col. RN60C 604 ohms			Z	Cabin ambient						
146		Resistor	Carbon Comp. 1.5K ohms 10% 1/2 watt			Z	Cabin ambient						
147		Resistor	Sci.Col. RN60D 1K ohms			Z	Cabin ambient						
148		Resistor	Carbon Comp. 100 ohms 10% 1/2 watt			Z	Cabin ambient						
149		Resistor	Sci.Col. RN60C 402 ohms			Z	Cabin ambient						
150		Resistor	Sci.Col. RN60D 15K ohms			Z	Cabin ambient						
151		Resistor	Sci.Col. RN60D 1 Meg ohms			Z	Cabin ambient						
152		Resistor	Sci.Col. 79PR50K 50K ohm pot.			Z	Cabin ambient						
153		Resistor	Sci.Col. 79PR100 100 ohm pot.			Z	Cabin ambient						

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

MLN	SSP-7514
PAGE	4 OF 4

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD (CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

SUBSYSTEM: Zero Gravity Whole Body Shower

ITEM NO.:

COMPONENT: Watthour Meter (continued)

DRAWING NO.: 89900000861-021.

DATE: April, 1973

REQUESTING ORGANIZATION: Martin Marietta Aerospace

SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher

CSD MRB APPROVAL (Concurrence)

CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN²)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
154		Resistor	Hytempco (select) 250 ohms			Z	Cabin ambient						Line nos 103 thru 157 are part of commercial unit, specific matl data unknown. Enclosed in metal housing, contained in ZGWBS metal elec. box.
155		Resistor	Sci.Col. RN60D 4.99K ohms			Z	Cabin ambient						
156		Coil Assy				Z	Cabin ambient						
157		Coil Form	Sci.Col. 11817 D&L Sales			Z	Cabin ambient						

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN: SSP-7515

SUBSYSTEM: Zero Gravity Whole Body Shower		DATE: April, 1973	CSD MRB APPROVAL (Concurrence)
COMPONENT: Temperature Control Unit	ITEM NO.:	REQUESTING ORGANIZATION: Martin Marietta Aerospace	
DRAWING NO.: 89900000861-037,-013,-095 & -105		SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher	CHAIRMAN:

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN²)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
158		Washer, Nylon (4)		Nylon	Used on front panel mounting screws	Z	Cabin ambient						Line nos 158 thru 182 are part of a commercial unit, specific material data unknown. Enclosed in metal housing, contained in metal ZGWBS elec. box.
159		Housing, Meter		Acrylic Plastic		Z	Cabin ambient						
160		Nylon Mounting		Black Nylon	L.E.D. Housing	Z	Cabin ambient						
161		Housing		Epoxy, Gallium, Arsenide, Phosphide	L.E.D. Housing	Z	Cabin ambient						
162		Front Housing, Phenolic			CTS-10K POT	Z	Cabin ambient						
163		Terminal Strip Housing		Comm. Grade Phenolic	Term. strip on back panel	Z	Cabin ambient						
164		Switch Slider		Black Bakelite	Slide switch slider	Z	Cabin ambient						
165		Frame		Phenolic	Slide switch frame	Z	Cabin ambient						
166		Philmore Knob	Athena P/N 337		Knob on front panel	Z	Cabin ambient						
167		Grommet, Nylon		Nylon	Spacer on back panel	Z	Cabin ambient						
168		Bobbin		Black bakelite, glass filled nylon	Relay contactor & coil	Z	Cabin ambient						
169		Resistors, carbon (15)		Carbon with glass filament, laminated	phenolic molding	Z	Cabin ambient						Line nos. 169 thru 182 apply to electronic circuitry in the unit. Specific material data unknown. Enclosed in metal housing, contained in metal ZGWBS elec. box.
170		Resistors, Precision (8)		Pro coat(R), silicone formulation		Z	Cabin ambient						
171		Capacitors (5)		Ceramic epoxy dipped		Z	Cabin ambient						
172		Capacitors, electronic (3)		Fluorocarbon sleeve, silicone rubber end seal		Z	Cabin ambient						
173		Bridge Rectifier		Black phenolic, epoxy encapsulant		Z	Cabin ambient						
174		Thermo Mounting Pads (2)		Nylon		Z	Cabin ambient						

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

MLN SSP-7515

PAGE 2 OF 2

SUBSYSTEM	Zero Gravity Whole Body Shower
COMPONENT	Temp. Control Unit (continued)
ITEM NO.	
DRAWING NO.	89900000861-037,-013,-095 & -105
DATE	April, 1973
REQUESTING ORGANIZATION	Martin Marietta Aerospace
SUBSYSTEM MANAGER (OR DESIGNEE)	E. A. Schumacher
CSD MRB APPROVAL (Concurrence)	
CHAIRMAN	

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN²)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
175		Zener Diodes (3)		Epoxy molded		Z	Cabin ambient						Line Nos. 169-182 apply to electronic circuitry in the unit.
176		Rectifiers (2)		Epoxy molded		Z	Cabin ambient						Specific material data unknown. Enclosed in metal housing, con-
177		Capacitor		Epoxy resin		Z	Cabin ambient						tained in metal ZGWBS elec. box.
178		CTS Pots (2)		Blue Delcrin(R), glass epoxy		Z	Cabin ambient						
179		Transformer		Paper & cloth insulation		Z	Cabin ambient						
180		Unitracks (2)		Molded polycarbonate resin		Z	Cabin ambient						
181		Printed Circuit Board		Glass epoxy fiberglass		Z	Cabin ambient						
182		Wiring				Z	Cabin ambient						

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

CREW SYSTEMS DIVISION SSP ETC/LSS MATERIALS REVIEW BOARD
(CSD/MRB)
NONMETALLIC MATERIALS MASTER LOG
(Prepare in Triplicate)

M.N SSP-7516

PAGE 1 OF 1

SUBSYSTEM: Zero Gravity Whole Body Shower	DATE: April, 1973	CSD MRB APPROVAL (Concurrence)
COMPONENT: ·Blower Modification Kit; ITEM NO.:	REQUESTING ORGANIZATION: Martin Marietta Aerospace	
DRAWING NO.: 89900000SK1	SUBSYSTEM MANAGER (OR DESIGNEE): E. A. Schumacher	CHAIRMAN

LINE NO.	WAIVER REQUEST NUMBER	MATERIAL GENERIC NAME	MANUFACTURER AND MATERIAL SPECIFICATION	MANUFACTURER'S MATERIAL DESIGNATION	INTENDED MATERIAL USAGE	USAGE CATEGORY D-NA-0002	USAGE ENVIRONMENT	WT. (lbs.)	EXP. AREA (IN^2)	BOARD DECISION ACPT.	COND. ACPT.	REJ.	REMARKS OR RECOMMENDATIONS
183		Air Blower	Rotron SL2EA2ABG		Substitute for SSP Blower	A,Y	Cabin ambient						Item. 183 *is* intended as substitute for the designed SSP blower.

MRB COMMENTS OR CONDITIONS OF ACCEPTANCE

MSC Form 1033 (Apr 72)

APPENDIX F

SSP/SHOWER ELECTRICAL INTERFACE CONNECTOR IDENTIFICATION

APPENDIX F

SSP SHOWER ELECTRICAL INTERFACE
CONNECTOR IDENTIFICATION

CN 1 - MAIN POWER CONNECTOR

PV7G14B5PNC (Shower Half)

Pin A - 115 VAC Primary Power, Phase A
B - 115 VAC Primary Power, Phase B
C - 115 VAC Primary Power, Phase C
D - 115 VAC Return
E - Single Point Ground

CN 11 - INSTRUMENTATION CONNECTOR

PV7G24B61SNC (Shower Half)

Socket A - Shield for Main Air Flow Cable
B - Main Air Flow Rate Signal (0-5 VDC)
C - Main Air Flow Rate Signal (0-5 VDC)
D - Shield for Main Air Temp Cable
E - Main Air Temp Signal (0-5 VDC)
F - Main Air Temp Signal (0-5 VDC)
G - Shield for Blower Current Cable
H - Blower Phase A Current Signal + (0-5 VDC)
J - Blower Phase A Current Signal - (0-5 VDC)
K - Shield for Water Pump Current Cable
L - Water Pump Phase A Current Signal + (0-5 VDC)
M - Water Pump Phase A Current Signal - (0-5 VDC)
N - Shield for Liquid Level Sensor 1 Current Cable
P - Liquid Level Sensor 1 Current Signal + (0-5 VDC)
R - Liquid Level Sensor 1 Current Signal - (0-5 VDC)
S - Main Air Temp, Platinum Resistance Sensor Lead A
T - Main Air Temp, Platinum Resistance Sensor Lead B
U - Main Air Temp, Platinum Resistance Sensor Lead C
V - Shield for Main Air Temp Cable
W - Main Power Breaker Phase B Voltage Tap (5 VAC)
X - Main Power Breaker Phase B Voltage Tap (5 VAC)
Y - Main Power Breaker Phase A Voltage Tap (5 VAC)
Z - Main Power Breaker Phase A Voltage Tap (5 VAC)

TABLE 11 (Cont)

a - Blower Switch Voltage Tap (5 VAC)
b - Blower Switch Voltage Tap (5 VAC)
c - Blower Phase A Voltage Tap (5 VAC)
d - Blower Phase A Voltage Tap (5 VAC)
e - Heater Switch Voltage Tap (5 VAC)
f - Heater Switch Voltage Tap (5 VAC)
g - Heater Voltage Tap (5 VAC)
h - Heater Voltage Tap (5 VAC)
i - Temp. Control Unit Voltage Tap (5 VAC)
j - Temp. Control Unit Voltage Tap (5 VAC)
k - Main Power Breaker Phase C Voltage Tap (5 VAC)
m - Main Power Breaker Phase C Voltage Tap (5 VAC)
n - Liquid Level Sensor 3 Voltage Tap (5 VAC)
p - Liquid Level Sensor 3 Voltage Tap (5 VAC)
q - Liquid Level Sensor 4 Voltage Tap (5 VAC)
r - Liquid Level Sensor 4 Voltage Tap (5 VAC)
s - Liquid Level Sensor 2 Voltage Tap (5 VAC)
t - Liquid Level Sensor 2 Voltage Tap (5 VAC)
u - Water Pump Phase A Voltage Tap (5 VAC)
v - Water Pump Phase A Voltage Tap (5 VAC)
w - Circuit Breaker 3 Voltage Tap (5 VAC)
x - Circuit Breaker 3 Voltage Tap (5 VAC)
y - Water Pump Phase B Voltage Tap (5 VAC)
z - Water Pump Phase B Voltage Tap (5 VAC)
AA - Water Pump Phase C Voltage Tap (5 VAC)
BB - Water Pump Phase C Voltage Tap (5 VAC)
CC - Blower Phase B Voltage Tap (5 VAC)
DD - Blower Phase B Voltage Tap (5 VAC)
EE - Blower Phase C Voltage Tap (5 VAC)
FF - Blower Phase C Voltage Tap (5 VAC)
GG - Bleed Air Flow Rate Signal (0-5 VDC)
HH - Bleed Air Flow Rate Signal (0-5 VDC)
JJ - Shield for Bleed Air Flow Cable

Table 11 (Cont)

CN 39 - HEAT EXCHANGER SIGNAL CONNECTOR

PV7G22B55PNC (Shower Half)

Pin A - 5 VDC Signal for Shower Shutdown
B - 5 VDC Signal for Shower Shutdown
C - 577-50 Temp Sensor A
D - 577-50 Temp Sensor A
E - Shield for 577-50 Temp Sensor A
F - 577-50 Temp Sensor B
G - 577-50 Temp Sensor B
H - Shield for 577-50 Temp Sensor B
J - 577-50 Temp Sensor C
K - 577-50 Temp Sensor C
L - Shield for 577-50 Temp Sensor C
M - 50308 Valve Open Command
N - 50308 Valve Close Command
P - 509-54 Valve Open Command
R - 509-54 Valve Close Command
S - 410-51 Valve Open Command
T - 410-51 Valve Close Command
U - Start Up Command
V - Shut Down Command
W - Commands Return
X - 50308 VPI Open
Y - 50308 VPI Close
Z - 50954 VPI Open
a - 50954 VPI Close
b - 410-54 VPI Open
c - 410-54 VPI Close
d - VPI 1 Return
e - VPI 2 Return
f - 115 VAC Monitor
g - 115 VAC Monitor
h - 115 VAC Martin Monitor

Table 11 (Cont)

i - 115 VAC Martin Monitor
j - 15 VDC Monitor Hi
k - 15 VDC Monitor Low
m - Shield for 15 VDC Monitor
n - V Reference Monitor Hi
p - V Reference Monitor Low
q - Shield for V Reference Monitor
r - POR
s - 50308 Valve Voltage
t - 50308 Valve Voltage
u - 50954 Valve Voltage
v - 50954 Valve Voltage
w - 410-51 Valve Voltage
x - 410-51 Valve Voltage
y - Shield for 50308, 509-54, and 410-51 Commands

The following are Martin interfaces with Hamilton Standard supplied shower hardware.

CN 16 - HEAT EXCHANGER SIGNAL CONNECTOR

PV6G22B55SNC (Martin Half)

Socket C - 577-50 Temp Sensor A
D - 577-50 Temp Sensor A
E - Shield for 577-50 Temp Sensor A
F - 577-50 Temp Sensor B
G - 577-50 Temp Sensor B
H - Shield for 577-50 Temp Sensor B
J - 577-50 Temp Sensor C
K - 577-50 Temp Sensor C
L - Shield for 577-50 Temp Sensor C
M - 50308 Valve Open Command
N - 50308 Valve Close Command
P - 509054 Valve Open Command

Table 11 (Cont)

R - 509-54 Valve Close Command

S - 410-51 Valve Open Command

T - 410-51 Valve Close Command

U - Start Up Command

V - Shut Down Command

W - Command Return

X - 50308 VPI Open

Y - 50308 VPI Close

Z - 50954 VPI Open

a - 50954 VPI Close

b - 410-54 VPI Open

c - 410-54 VPI Close

d - VPI 1 Return

e - VPI 2 Return

g - 115 VAC Monitor

h - 115 VAC Martin Monitor

i - 115 VAC Martin Monitor

j - 15 VDC Monitor Hi

k - 15 VDC Monitor Low

m - Shield for 15 VDC Monitor

n - V Reference Monitor Hi

p - V Reference Monitor Low

q - Shield for V Reference Monitor

r - POR

s - 50308 Valve Voltage

t - 50308 Valve Voltage

u - 50954 Valve Voltage

v - 50954 Valve Voltage

w - 410-51 Valve Voltage

x - 410-51 Valve Voltage

y - Shield for 50308, 509-54, and 410-51 Commands

Table 11 (Cont)

CN 17 - HEAT EXCHANGER POWER CONNECTOR

PV6G14B5SNC (Martin Half)

Socket A - 115 VAC Input

B - 115 VAC Return

C - Frame Ground

D - Auxillary 115 VAC Power

CN 19 - BLOWER CONNECTOR

PV6G14B5SNC (Martin Half)

Socket A - 200 VAC Phase A

B - 200 VAC Phase B

C - 200 VAC Phase C

D - 200 VAC Return

E - Frame Ground

CN 21 - HEATER CONNECTOR

PV6G12B3SNC (Martin Half)

Socket A - 115 VAC Input

B - 115 VAC Return

C - Frame Ground

CN 31 - WATER PUMP CONNECTOR

PV6G10B6NC (Martin Half)

Socket A - 200 VAC Phase A

B - 200 VAC Phase B

C - 200 VAC Phase C

D - 200 VAC Return

E - Frame Ground